WATER WORKS & SEWERAGE

THE NEW FILTRATION PLANT AND PUMPING STATION
OF THE SPRINGFIELD CITY WATER COMPANY—SPRINGFIELD, MISSOURI

THE world over, cast iron pipe is the recognized standard for underground mains. Many of the earliest installations in Old World cities, upwards of three centuries ago, are still in active use. Throughout the United States, more than 200 cities are obtaining satisfactory service from their *original* cast iron water and gas mains. In Central and South America, large quantities of our pipe are being installed. With improved laying methods and manufacturing processes, U. S. Cast Iron Pipe can be confidently expected to equal or exceed the remarkable service records of cast iron pipe as made centuries ago.

UNITED STATES PIPE & FOUNDRY CO., General Offices: Burlington, N. J.

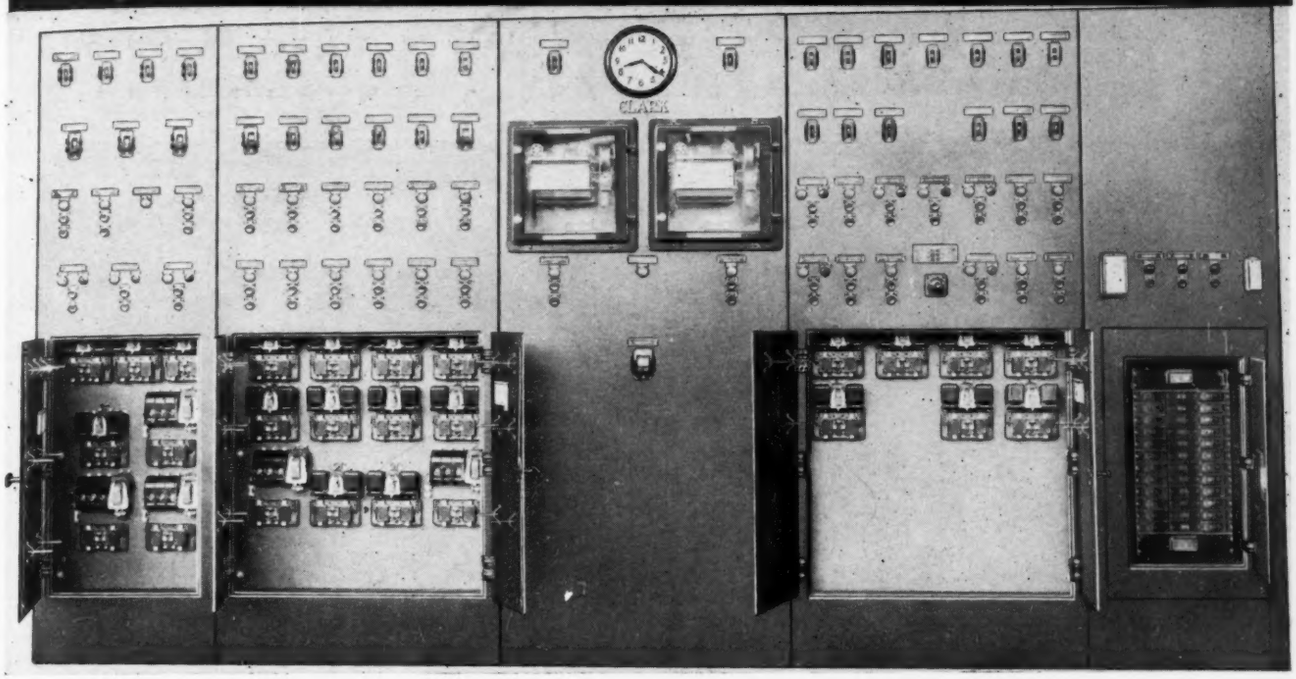
Plants and Sales Offices throughout the U. S. A.

Lithographed on stone by Edward A. Wilson. Copyright 1941, U. S. Pipe & Foundry Co.

U.S. cast iron PIPE

Centrifugally or Pit Cast for water works, gas, sewerage, drainage and industrial services.

26 Motors Clark Controlled



¶ This Main Station, 5 Panel Board erected in an Eastern Sewage Treatment Plant provides adequate protection and control for 26 motors, ranging from ¼ hp. to 70 hp.

¶ These motors operate Draft Fans, Compressors, Filters, Vacuum Pumps, Sludge Pumps, Agitator Pumps, and Chemical Treatment Pumps. A 70 hp. Crane motor is also controlled from this board.

¶ Each motor starting unit is equipped with Disconnect Circuit Breaker, Across-the-line Starter with Overload Protection, and with the necessary Push Button Stations, Selector Switches, and Indicating Lights in accordance with the use and/or operation of the starter.

¶ This is a completely Dead Front, Sheet Steel Enclosed, Cubicle Type Control Panel, with all Indicating Lights, Push Buttons, and similar accessories flush mounted.

¶ A 24 Circuit Lighting Panel, Electric Clock, and Recording Meters also are flush mounted, but doors in the lower part of the panels provide easy access to all starting equipment.

¶ Such an installation provides the maximum safety, not only to equipment, but prevents tampering by unauthorized persons.

¶ "3C" Engineers will gladly consult with you on Water Works and Sewage Treatment Plant Electrical Control Problems—

OFFICES IN PRINCIPAL CITIES

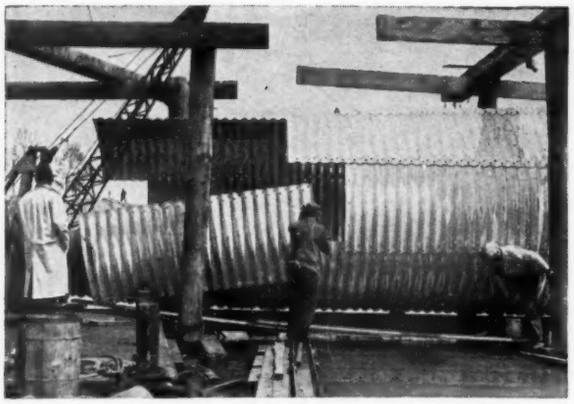
THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

WATER WORKS & SEWERAGE, June, 1941. Volume 88. Number 6. Published monthly at 330 South Wells Street, Chicago, Ill., by the Gillette Publishing Company. Per copy, 50c. Subscription rate, United States $2.00 per year; Canada $2.40 per year; Foreign $3.00 per year. Copyright, 1941. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under Act of March 3, 1879.

A LOW-COST ANSWER FOR Every DRAINAGE PROBLEM

SEWERS: Say goodbye to costly maintenance by using Asbestos-Bonded ARMCO Sewer Pipe. Flexible, corrugated design and tightly coupled joints help prevent breakage and infiltration. Long material life is assured by a galvanized metal base of ARMCO Ingot Iron, plus a thick pavement and a full bituminous coating tightly bonded to the pipe.



LARGE WATERWAYS: Cut the cost of sewers, bridges and other large waterways by building them with ARMCO Multi Plate Pipe or Arches. Heavy-gage corrugated metal sections are shipped in knocked-down form ready for assembly. Unskilled men can bolt them together and backfill with earth. No special equipment is needed and the job is done quickly.

LIMITED HEADROOM: You'll find ARMCO Pipe-Arches ideal for drainage under limited headroom. They provide ample water-carrying capacity and the crossing is level. Supplied in long lengths, easily joined by sturdy band couplers into a continuous conduit of uniform strength. Heavy loads, traffic impact and severe frost action are no hazards.

SHEETING: You'll save time and money by using ARMCO Sheeting for trenches, foundations and similar work. The corrugated design combines strength with light weight for easy handling and speedy installation. It drives fast to full penetration. Average job costs are surprisingly low, since ARMCO Sheeting can be pulled and used again and again.

Call THE ARMCO MAN

The easy way to solve drainage or earth retention problems is to call in the ARMCO man. He has a complete line of products in a wide range of sizes and gages to meet every requirement. This with his practical experience will save you time and money.

Remember too that you can use any ARMCO product with complete confidence in its strength, durability and economy. All are backed by a 35-year record of successful service under all kinds of conditions. For complete facts call in your local ARMCO man or write us direct. ARMCO DRAINAGE PRODUCTS ASSN., 5064 Curtis St., Middletown, O.

ARMCO DRAINAGE PRODUCTS

Rensselaer's Latest Contribution to Quality in Valves and Hydrants is . . . Sorbo-Mat Iron

16-inch Hub End Non-rising Stem A.W.W.A. Double Gate Valve.

Testing 6" A. W. W. A. Valve to 1,000 pounds per square inch

5-inch Genuine Corey Fire Hydrant.

A.W.W.A. Specifications for Cast Iron Valves and Hydrants call for working pressures of 150 pounds and hydrostatic pressure tests of 300 pounds per square inch. As shown above, the Sorbo-Mat Iron Specification used in all our castings is regularly subjected to hydrostatic test pressures several times greater than specified. The fine grain of this metal, plus its uniformity of strength and density, as well as freedom from chilled surfaces, hard spots, porous areas and cavities, is our customer's assurance of superior pressure tightness and resistance to the corrosive media in water and sewage.

CONTROLLED SPECIFICATION CAST IRONS
STRUCTURE STRENGTH SERVICE
SORBO-MAT

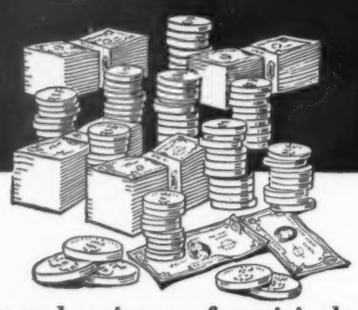
Consult our general catalog "G" and bulletins "K", "Q" and "V" for complete information, or write us concerning your valve and hydrant requirements.

RENSSELAER VALVE CO.

TROY, NEW YORK

CASH PRIZES!

Tell us how you used Perchloron for emergency water purification



Here's a prize contest especially for superintendents and engineers of municipal water works. Twenty-five dollars ($25.00) will be paid by Penn Salt for each outstanding case history of emergency water purification with Perchloron. Five dollars ($5.00) will be paid for similar case histories not judged worthy of major prizes, but deserving recognition.

Send your entry... 500 words or less... today to Pennsylvania Salt Manufacturing Co., Widener Bldg., Phila., Pa. The contest closes on October 1, 1941.

A TYPICAL PERCHLORON CASE HISTORY

This is an outline of the sort of story that may win you a prize: The quality of a section of a city's public water supply was being questioned because of the positive presumptive B. Coli tests in one suburban section, despite the fact that negative samples only were obtained on the balance of the distribution system. Pollution was thought to be entering the main somewhere between the city proper and this suburb.

Pending location and correction of the source of the pollution, emergency disinfection was attained by continuously injecting a solution of Perchloron into this main. This was done by a conventional hypochlorite pressure feeding pump, which delivered the Perchloron solution into the main through an emergency tap. The quantity added was sufficient to attain the desired disinfecting residual after 20 minutes' contact, and the 16 miles of feeder main provided the desired retention period.

Thanks to Perchloron, this section was assured of a safe water supply until the source of pollution could be discovered and the trouble corrected.

Perchloron, dustless and dry, a free-flowing and readily dissolved powder containing more than 70% available chlorine, is also useful for sanitizing new mains, for clear wells and filters, and for swimming pool sanitation. Packed 9 handy-sized cans to the case, each can with airtight cover; also in 100-lb. drums. Write for the new handsomely illustrated booklet on Perchloron.

Perchloron

REG. U.S. PAT. OFF.

PENNSYLVANIA SALT
MANUFACTURING COMPANY
Chemicals

1000B WIDENER BUILDING, PHILADELPHIA, PA.
NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • WYANDOTTE • TACOMA

Here it is . .

The EMPIRE STREEEMLINE METER

The Empire STREEEMLINE, a four bolt, frost-protected meter, is a thoroughly modernized version of the well known National Empire Meter. It embodies the same basic principle of oscillating piston measurement that has been time proven in hundreds of thousands of Empire Meters.

Results from the extensive Pittsburgh-National program of research and development are obvious in the STREEEMLINE. The numerous improvements and refinements built into this meter provide even superior performance and add materially to the important aspects of accuracy, long life and accessibility.

See this outstanding development in meter design and construction in the Pittsburgh-National exhibit booths at the A.W.W.A. Convention in Toronto. A new bulletin giving complete information on the Empire STREEEMLINE will be mailed upon request.

FEATURES

- **TWO-PART, SNAP-JOINT MEASURING CHAMBER**—Scientifically designed and proportioned with dual inlet and outlet ports. Provides accuracy even superior to Empire Meters built in the past.
- **EMPIRE BALANCED PISTON**—Time proven oscillating piston design, with piston pilot, results in exceptional accuracy on low flow rates and assures sustained, quiet operation.
- **OIL ENCLOSED GEAR TRAIN**—Ingenious four-wheel design, utilizing top half of measuring chamber as bottom plate. All spindles operate in fully enclosed rubber bushings. Rugged gears, with special tooth, for quietness and sensitivity.
- **ALL WORKING PARTS ASSEMBLE AS COMPLETE UNIT, WITHOUT USE OF SCREWS**—Only meter made with oil enclosed gear train having but three interior castings. Designed for simplicity, compactness and utmost accessibility. Snap-joint construction with dowel pins assures absolute alignment between measuring chamber and intermediate train.
- **COMPLETE FROST PROTECTION**—The cast iron bottom plate, corrosion protected with a coat of RESISTIN, is designed to break in event of freezing. Since both measuring chamber and enclosed intermediate gear train housing utilize snap-joint construction, without screws, the parts will separate when the frost bottom plate breaks, thereby relieving the working parts from strain and distortion. This design provides the first fully frost-protected enclosed gear train.
- **CIRCULAR DIAL REGISTERS**—Either straight or circular reading type, having large, red, center test hand, recording in gallons, cubic feet or other units of measurement.

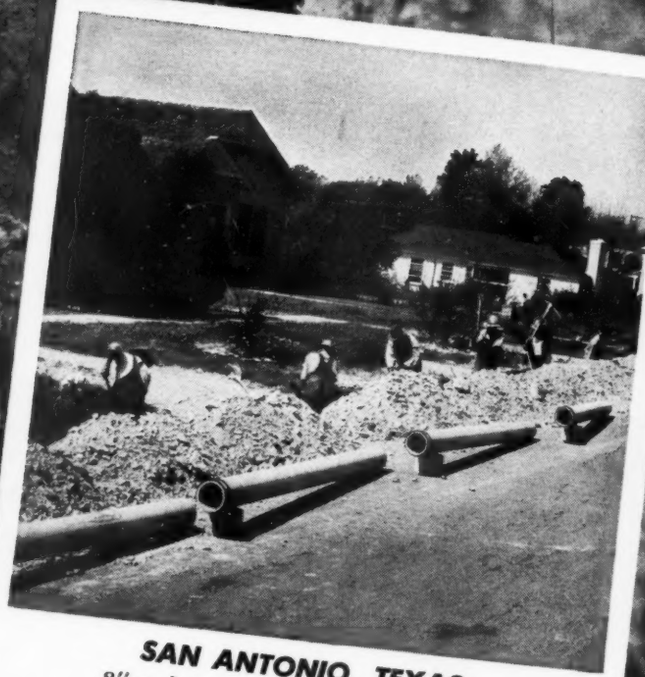
SEE US AT THE 61ST ANNUAL MEETING AWWA JUNE 22 26 1941 ROYAL YORK HOTEL TORONTO CANADA

NATIONAL METER DIVISION
PITTSBURGH EQUITABLE METER COMPANY
4207 FIRST AVENUE BROOKLYN, N.Y.

Nicol

Are you taking advantage of THIS BASIC ADVANCE in WATER-LINE ENGINEERING?

GRANVILLE, N. Y.
Various sizes Class 150 Transite Pipe for complete new system.



SAN ANTONIO, TEXAS
8" and 12" Class 150 Transite Pipe.

JM PRODUCTS JOHNS-MANVILLE

Johns-Manville

. . . hundreds of American communities are enjoying more efficient, lower cost water service with Johns-Manville Transite Pipe. Made of asbestos and cement, this better water carrier offers these basic advantages:

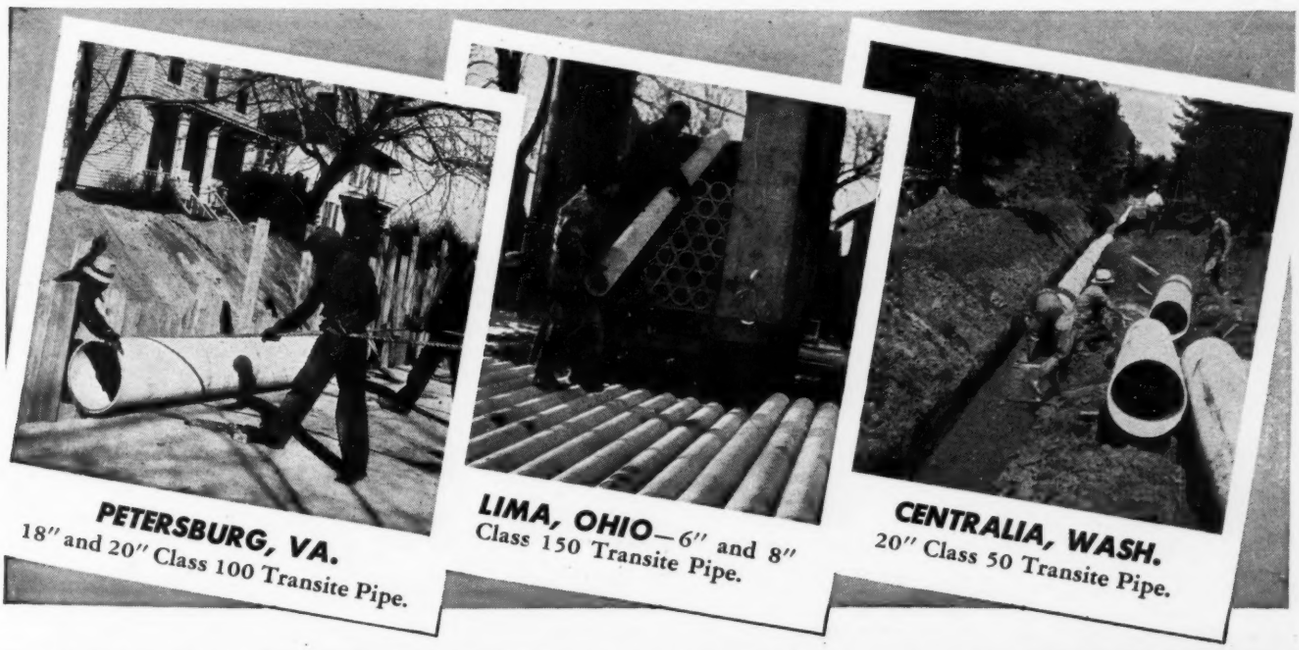
"Packaged" joint speeds up assembly. Transite Pipe is assembled with the Simplex Coupling, a prefabricated, "packaged" joint. No heating or caulking is required . . . the need for large bell holes is eliminated. Joints stay tight in service . . . keep leakage to a minimum even though assembly is so simple that unskilled crews can finish jobs in the shortest possible time. And because Transite Pipe is light in weight and easy to handle, installation costs are still further reduced.

Delivery capacity stays high. Transite's smooth interior surface offers an initial high flow coefficient of C=140. Because Transite is made of two nonmetallic minerals . . . asbestos and cement . . . this high carrying capacity can never be reduced by tuberculation. Pumping costs stay low. And, in many cases, this advantage of Transite permits the use of smaller diameter pipe with resulting savings in the numerous items that make up the original cost of completed water lines.

Maintenance is negligible. Transite's asbestos-cement composition provides unusual resistance to corrosion. It is immune to electrolysis. And Transite's durability and uniform strength permit accurate and efficient design of water lines.

Full details will show you other ways that Transite Pipe helps cut water-line costs and improve efficiency. Send for brochure TR-11A. And for information on more economical sewer lines, write for Transite Sewer Pipe brochure TR-21A. Address Johns-Manville, 22 East 40th Street, New York, N. Y.

BE SURE TO ATTEND the 61st Annual Meeting of the American Water Works Association, Toronto, Canada, June 22nd to June 26th.



PETERSBURG, VA. 18" and 20" Class 100 Transite Pipe.

LIMA, OHIO—6" and 8" Class 150 Transite Pipe.

CENTRALIA, WASH. 20" Class 50 Transite Pipe.

TRANSITE PIPE

AN ASBESTOS PRODUCT

For efficient, economical water and sewer lines

Something Entirely New!

IN WATER TREATING EQUIPMENT

THE GRAVER REACTIVATOR*

HERE is a water treating development that tops any equipment on the market. It is a condensed unit that softens and clarifies your water supply—reduces the reaction and settling time, of from 4 to 8 hours, to not more than 60 minutes—and actually improves the quality of water delivered over that obtainable from a conventional type settling tank.

UPWARD SLUDGE FILTRATION—that's the principle that "delivers the goods," and it's an exclusive Graver feature (patented).

Actual tests on water of 20 grain hardness per gallon and 200 p.p.m. of turbidity resulted in reduction of hardness to approximately 3 grains per gallon and turbidity to 20 p.p.m.

Here is equipment that certainly warrants immediate investigation. Can you afford not to know all about it? No obligation!

Clip this Coupon and Mail Today

GRAVER TANK & MFG. CO., INC.
5008 Tod Avenue East Chicago, Ind.

Please send more information on the Graver Reactivator.
Also send complete data sheets on the following:

- ☐ Aeration
- ☐ Baffle Plate Aerator
- ☐ Coke Tray Aerator
- ☐ Oil Removal Filters
- ☐ Diffuser Type Aerator
- ☐ Taste and Odor Removal Filters
- ☐ Raschig Ring Aerator

Name .....
Company ..... *Title* .....
City ..... *State* .....

* Patented and Patents Pending

GRAVER TANK & MFG. CO., INC.

NEW YORK
CATASAUQUA, PA

5008 Tod Avenue
EAST CHICAGO, IND.
CABLE ADDRESS—GRATANK

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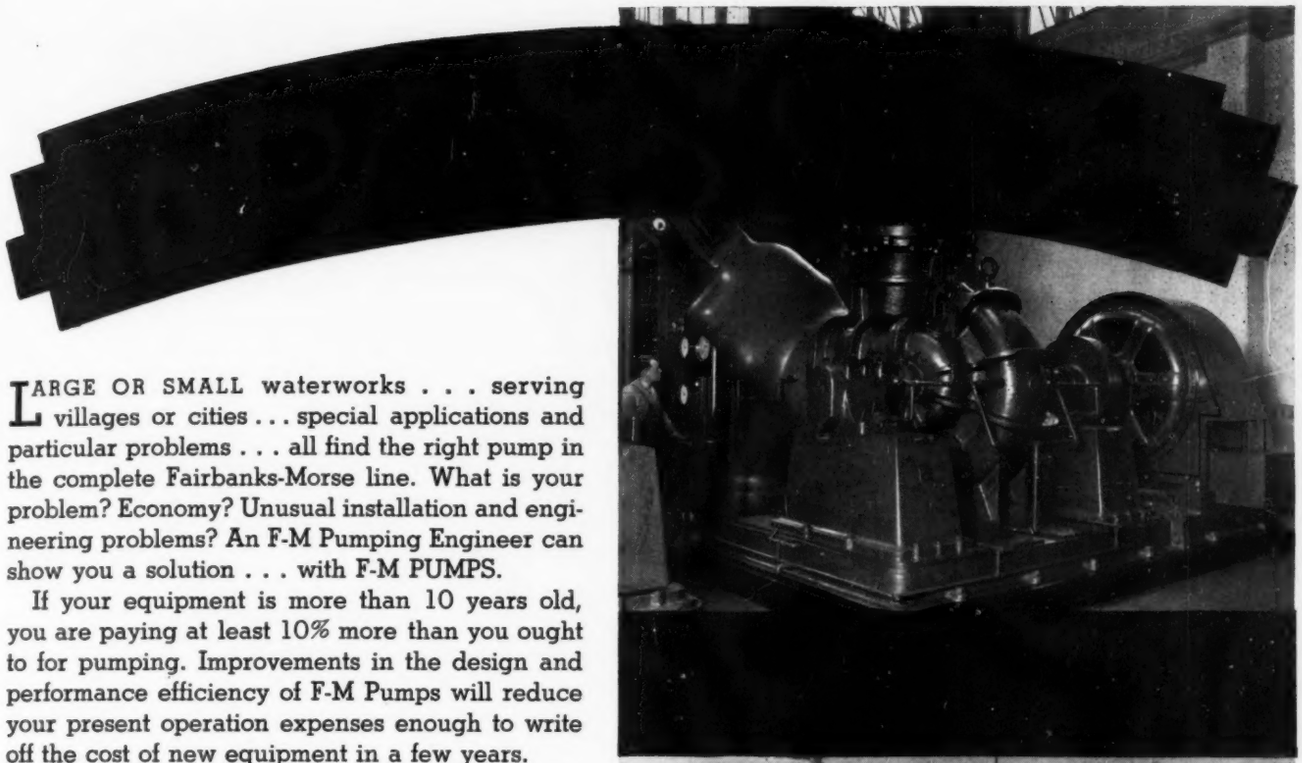
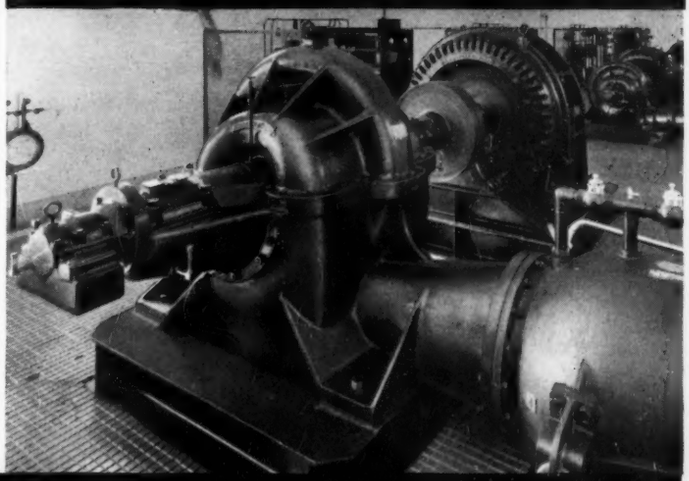


LARGE OR SMALL waterworks . . . serving villages or cities . . . special applications and particular problems . . . all find the right pump in the complete Fairbanks-Morse line. What is your problem? Economy? Unusual installation and engineering problems? An F-M Pumping Engineer can show you a solution . . . with F-M PUMPS.

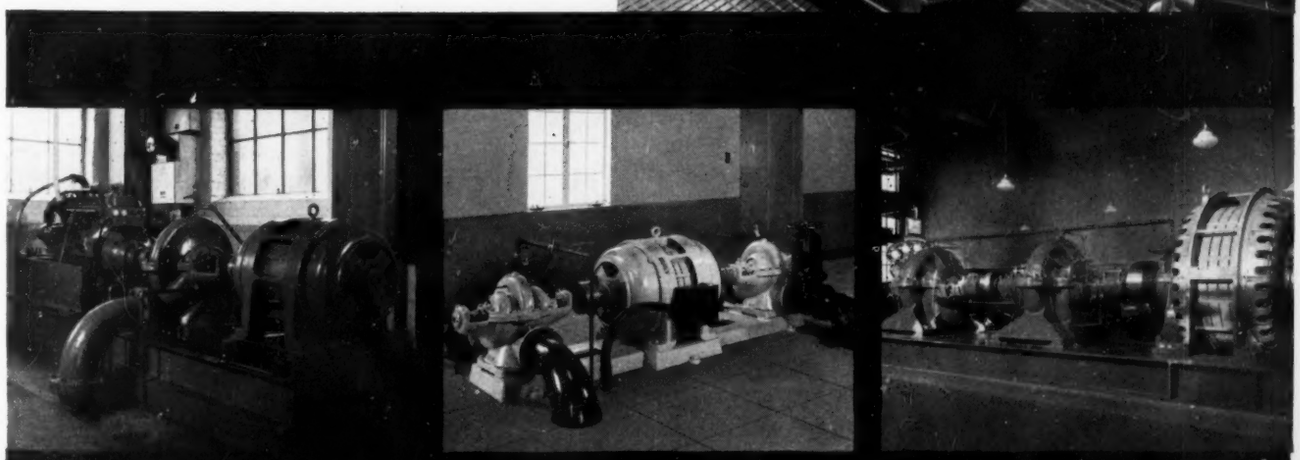
If your equipment is more than 10 years old, you are paying at least 10% more than you ought to for pumping. Improvements in the design and performance efficiency of F-M Pumps will reduce your present operation expenses enough to write off the cost of new equipment in a few years.

Actual records in countless waterworks installations prove the economy and dependability of F-M Pumps. They can work as efficiently and economically for you. Write Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago. Branches and Service Stations throughout United States and Canada.



THE COMPLETE F-M LINE

Deep Well Turbine Pumps—Double Suction Centrifugal Pumps—Side Suction Centrifugal Pumps—Builtogether Centrifugal Pumps—Centrifugal Trash Pumps—Multi-Stage Centrifugal Pumps—Angle-Flow Centrifugal Pumps—Vertical Centrifugal Pumps—Propeller Type Pumps—Rotary Pumps—Reciprocating Power Pumps—Reciprocating Steam Pumps—and Special Equipment.



FAIRBANKS · MORSE PUMPS

DIESEL ENGINES ELECTRICAL MACHINERY RAILROAD EQUIPMENT WASHERS-IRONERS STOKERS
MOTORS FAIRBANKS SCALES WATER SYSTEMS FARM EQUIPMENT AIR CONDITIONERS

LATEST ADVANCE

ROCK ISLAND USES ONE INCINERATOR

Faced by the necessity of disposing of its Sewage and Garbage, the city of Rock Island, Illinois, decided that, economically, the logical procedure would be to build one plant to do both jobs.

To ensure complete flexibility in operation, the Incinerator was specified to meet the following exacting requirements:

- To incinerate a combination of green garbage and sewage filter cake.
- To incinerate green garbage alone.
- To incinerate sewage filter cake alone.
- To operate under strict guarantees on any of the above bases.

When you have a problem in the disposal of sewage sludge, or garbage, or both, write "Incineration Headquarters" and take advantage of the authoritative service, backed by wide experience and intensive research, which we can give you.

NICHOLS ENGINEERING & RESEARCH CORPORATION

60 WALL TOWER BLDG., NEW YORK, N. Y. NERCO UNIVERSITY TOWER BLDG., MONTREAL, P. Q.

ALUMINUM, DEFENSE, AND YOU

ALCOA

3

IT IS EASY TO UNDERSTAND ABOUT ALUMINUM AND DEFENSE

THE WHOLE THING BOILS DOWN to two simple questions:

1. **How much aluminum** are America and England going to need? There is only one answer: The democracies must have *all the aluminum it takes to win,* and nobody knows how much that is.
2. **How fast** is aluminum needed? We don't know, for sure, but just as fast as the aircraft plants, munition plants, shipyards, and the like, can be expanded to use aluminum and other materials for defense purposes.

THOSE IN AUTHORITY IN WASHINGTON are putting together, day by day, expert estimates of what all these defense industries are going to need, month by month, clear to the end of 1942. These estimates, as issued, are our book of rules.

FOR MONTHS WE HAVE BEEN, and are now, delivering aluminum for defense purposes far in excess of that called for by prior estimates.

DEFENSE IS NOW TAKING from us over 40 million pounds a month. Every American ought to have a picture of just how much aluminum that is; here it is:

Peace-time America, during the nine years from 1930-8, could find use for only 14 million pounds a month from us.

In the busy year of 1939 we had to make only 27 million pounds a month to satisfy the civilian needs of this prospering country.

Suddenly, defense alone needs 40 million a month! 14 million (civilian), to 27 (civilian), to 40 (defense) and soon to 50 and beyond!

★ ★ ★ ★

YOU CIVILIAN USERS of aluminum are grand people.

THE WAY YOU ARE DOING WITHOUT aluminum until producers can catch up again with civilian uses is typically American. We are sincerely grateful for your understanding.

IN THIS RECESS you are having to scramble for **RECESSITIES**—other materials which just don't fill the bill 100%, because there is no pat substitute for aluminum.

IT'S TOUGH ON YOU and it's hard on us to have to turn away temporarily from the friends and pursuits of a lifetime.

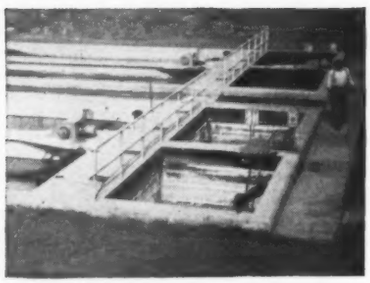
WE HAVE NOT TURNED OUR BACKS!

WE INTEND that no civilian shall have to forego the things aluminum can do best one minute longer than we can help.

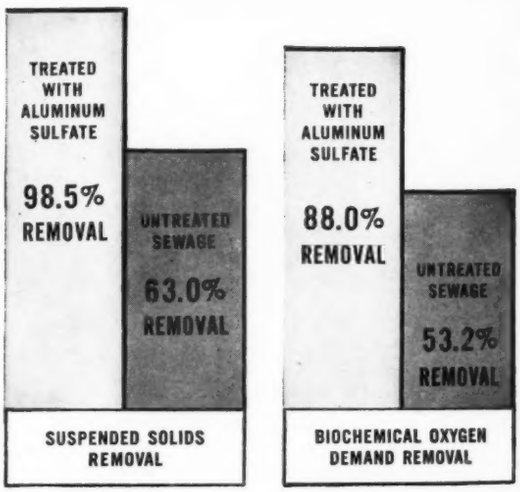
ALUMINUM COMPANY OF AMERICA

Sewage Plant Reports

98.5% SOLIDS REDUCTION WITH GENERAL CHEMICAL ALUMINUM SULFATE



Chemical Treatment Reduces River Pollution Resulting from Cannery, Broom Factory, Milk and Soy Bean Plant and Domestic Wastes



Domestic sewage and wastes from small industries in a mid-western town are combined and pass through fine screens to flash mixers and then through slow mixing or flocculating chambers to the sedimentation basins.

Because of efficient plant operation, reduction of 63% of suspended solids and 53% of B.O.D. is accomplished during those months when chemicals are not used for coagulation and clarification.

However, during warm summer months when river flow is lowest and the organic load is greatest, additional removals of suspended and dissolved organic matter are required so as to prevent objectionable pollution of the river into which the effluent flows.

General Chemical Aluminum Sulfate, fed in amounts of 50 to 85 parts per million, jumps suspended solids removal to an average of 83% and a maximum of 98.5%. Similarly, B.O.D. reduction is increased to an average of 73% and ranges as high as 88%. These remarkable reductions in suspended and dissolved organic matter result from effective coagulation and settling of the coagulated material. Patches of crystal clear water are seen in the flocculators and a clear, colorless effluent flows from the settling basins to the river.

Sewage plant operators and consulting engineers having similar problems are offered, without obligation, the cooperation of General Chemical Technical Service toward the solution of their problems.

GENERAL CHEMICAL COMPANY

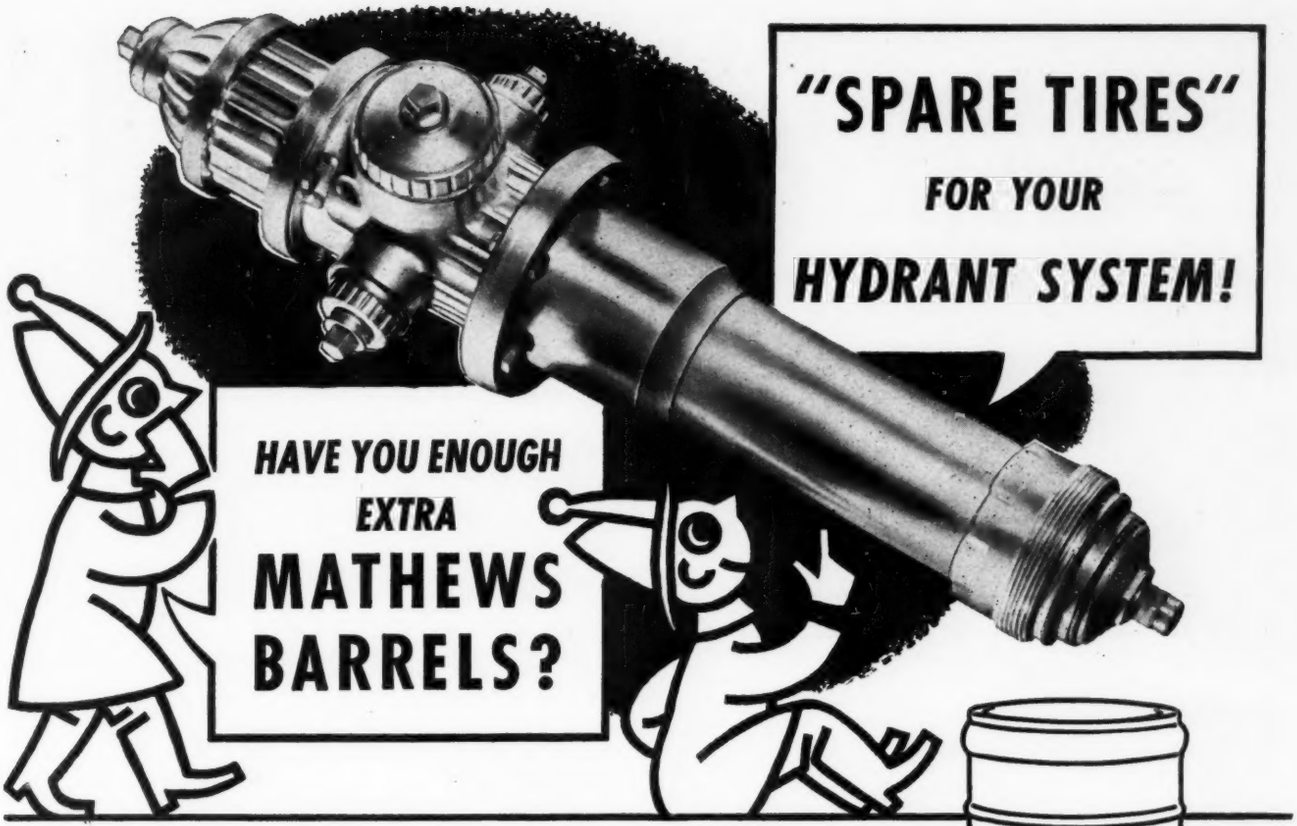
40 RECTOR STREET, NEW YORK, N. Y.

Sales Offices: Atlanta • Baltimore • Boston • Buffalo • Charlotte (N. C.) • Chicago • Cleveland Denver • Detroit • Houston • Kansas City • Milwaukee • Minneapolis • Newark (N. J.) • New York Philadelphia • Pittsburgh • Providence (R. I.) • St. Louis • Utica (N. Y.)

Pacific Coast Sales Offices: San Francisco • Los Angeles

Pacific Northwest Sales Offices: Wenatchee (Wash.) • Yakima (Wash.)

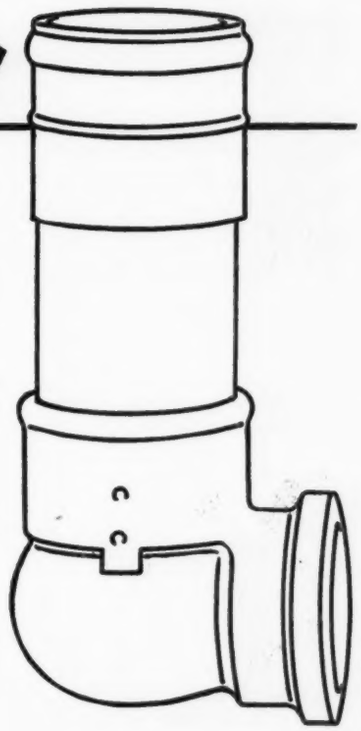
In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver



70 years ago the removable barrel was a *basic* improvement in hydrant design. Today it is still the *basic* advantage of the Mathews Hydrant. Here's why:

1. A smashed barrel, unscrewed and replaced with a spare barrel, makes an immediate repair without digging.
2. Inserting a spare barrel allows inspection or overhaul in the shop of all operating parts, including main and drain valve *seats*.
3. Without digging, modern steamer nozzles can be added, and grade levels can be changed up or *down*.
4. The barrel, surrounded by its loose protection case, gives double impact strength and prevents frost-heaved ground from straining the hydrant.

SO—if you are buying new hydrants, specify Mathews. If you *have* Mathews, check your supply of spare barrels this week.



MATHEWS HYDRANTS

Made by R. D. WOOD COMPANY

Manufacturers of Sand Spun Pipe (centrifugally cast in sand molds) and R. D. Wood heavy-duty gate valves for water works

400 CHESTNUT STREET, PHILADELPHIA, PA.

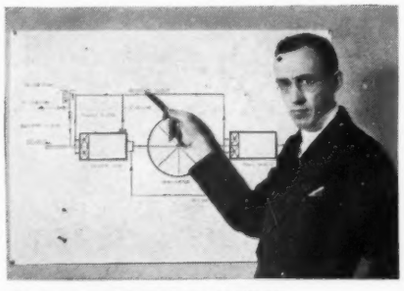
AND THAT'S NOT ALL AERO-FILTER WILL DO!

① AERO-FILTER IS SMALLER! Filter bed volume is 1/7 to 1/9 the size of conventional filters. This is made possible because of Aero-Filter's efficient distribution of sewage to the filter bed. It also has other low-cost advantages! . . . . .

② NO COSTLY PUMPING for recirculation, nor oversize primary settling tanks are required with Aero-Filter's rain-like distribution. Maintenance and power costs are lowered. Lower initial plant cost also reduces fixed charges. . . .

③ ADEQUATE PURIFICATION for any requirement—is now available with Aero-Filters. By a choice of single or two-stage design and supplementary units, any degree of effluent quality may be secured at minimum cost. . . . . .

④ THESE 49 INSTALLATIONS in both northern and southern climates — approval by state boards of health, and several years of proved service, give conclusive evidence that Aero-Filter superiority is a well established fact among men who know. . . . . .



⑤ AND AERO-FILTER SLUDGE can be concentrated in the primary tank, combining it with the primary sludge before pumping to the digesters. This reduces to a minimum the heat loss and the supernatant solids discharge due to sludge pumping. . . . . .

⑥ REX SANITATION EQUIPMENT also includes other vital equipment for the Aero-Filter plant . . . bar screens, triturators, grit collectors and washers, conveyors, Tow-Bro sludge collectors, rapid and Slo-Mixers, etc. Get copies of catalog on those items you find interesting.

P.S. *We feel you'll be as favorably impressed with Aero-Filter as this engineer was after this conversation. Send today for an Aero-Filter catalog—also others on the complete line of Rex Sanitation Equipment. Address 1610 W. Bruce Street, Milwaukee, Wisconsin.*

REX SANITATION EQUIPMENT

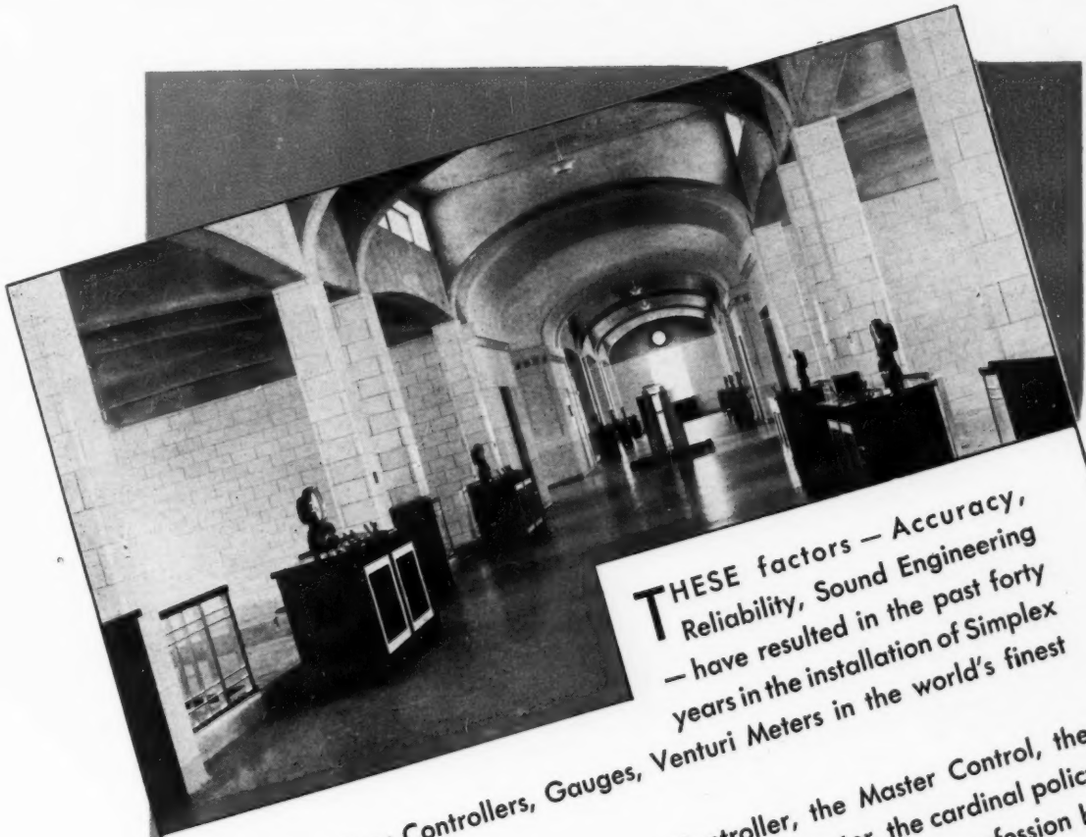
CHAIN BELT COMPANY OF MILWAUKEE

Baldwin-Duckworth Chain Belt Division, Springfield, Massachusetts • Worcester, Massachusetts
Rex Chain Belt and Conveyor Divisions, Milwaukee, Wisconsin

50TH ANNIVERSARY 1891 REX 1941 CHAIN BELT COMPANY

SIMPLEX

FOR ACCURACY • RELIABILITY • SOUND ENGINEERING IN FILTRATION PLANT EQUIPMENT



THESE factors — Accuracy, Reliability, Sound Engineering — have resulted in the past forty years in the installation of Simplex Rate of flow Controllers, Gauges, Venturi Meters in the world's finest filtration plants.

First to develop the Direct-acting Controller, the Master Control, the Bell-shaped Float, and the Sand Expansion Indicator, the cardinal policy of Simplex is to increase its usefulness to the waterworks profession by continued research, design and cooperative measures with both designing and operating engineers.

SIMPLEX PLEDGES ITS ENTIRE FACILITIES TO MEET THE DIVERSE PROBLEMS OF THE NATIONAL EMERGENCY.

Visit our booth — A. W. W. A. Convention, Toronto June 22-26, 1941

Simplex Valve & Meter Company
68TH & UPLAND STS.
PHILADELPHIA

They Started Something!

THE BASIC PRINCIPLES that were applied in the simple telescopes of the early astronomers have been utilized in countless ways to widen the scope of man's knowledge and to promote industrial progress and human welfare. The refinements in optical instruments that have culminated in the giant telescopes of today have cast new light on the movements of heavenly bodies, on their size and chemical composition.

In other fields of science, also, optical instruments have played an essential part. The development of the microscope gave industry a new and valuable implement for obtaining basic data on materials and processes. With the aid of the microscope, medical science was able to open whole new fields of knowledge in the cause and treatment of diseases. The men who first discovered that lenses can be used to magnify objects made striking contributions to progress.

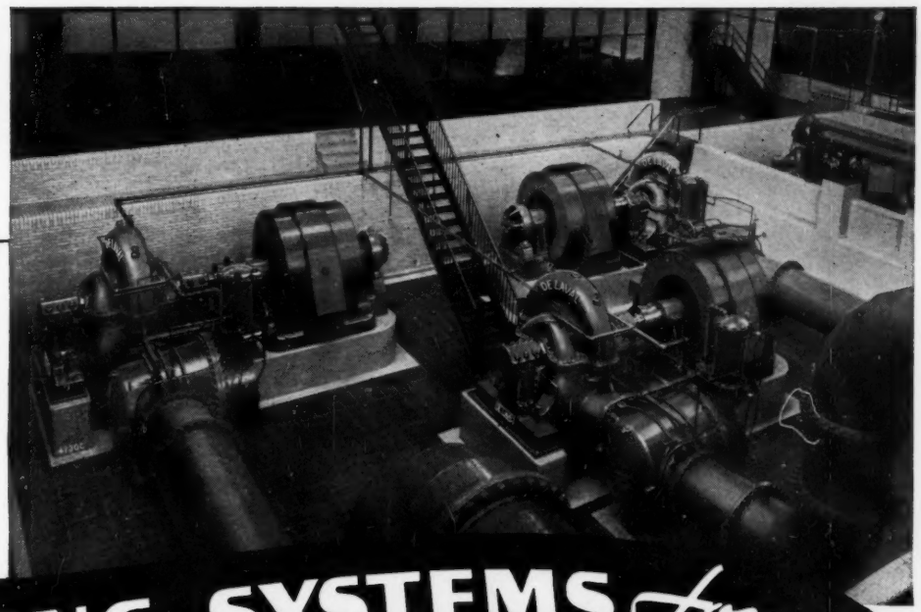
When EBG engineers first made Liquid Chlorine commercially available in America, their work, too, had far-reaching effects in industry and in human welfare. EBG Liquid Chlorine gave municipalities a new means for controlling water-borne diseases by the effective purification of water supplies—and today it is expanding its usefulness in the newer field of sewage sterilization. And EBG Liquid Chlorine gave to the paper and textile industries an unusually effective and economical agent for bleaching processes.

The first cylinder of Liquid Chlorine made by EBG in 1909.

EBG engineers are pioneers in the production and servicing of Liquid Chlorine—profit by their *extra* experience when you buy.

ELECTRO BLEACHING GAS COMPANY
Main Office: 60 East 42nd Street, New York, N.Y.
Plant: Niagara Falls, N. Y.

EBG Liquid Chlorine
FIRST IN THE COUNTRY



These three De Laval 50 m.g.d. motor-driven pumps in the Ward Station, Buffalo, are kept primed at all times by a De Laval automatic priming system.

Automatic PRIMING SYSTEMS for DE LAVAL PUMPS

THE De Laval Submerged Suction Priming System automatically keeps the water in the supply line and all connections on the suction side of one or a number of centrifugal, mixed flow or propeller pumps above the eye of the impeller at all times, just as if the pumps were actually located below the supply.

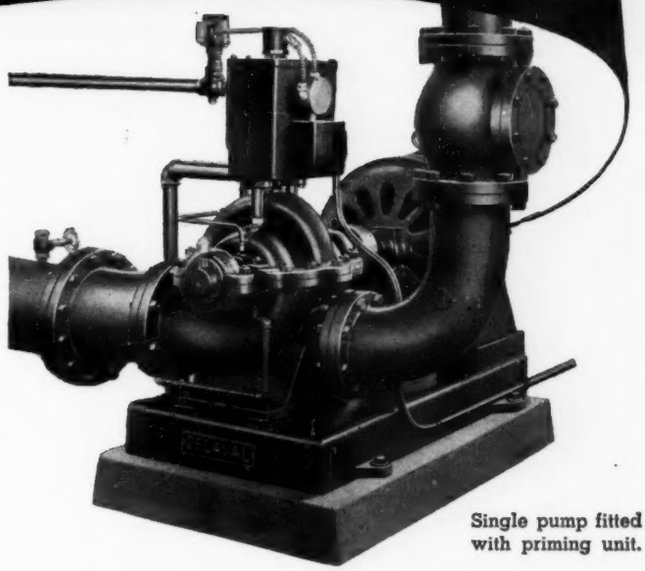
It does not affect the construction or normal operation of the pump itself. The head-capacity characteristic, the efficiency and the required horsepower of the pump remain as before.

Normally, discharge begins immediately a pump is started, but if for any reason the priming should be lost, as from a break in the suction line, the pump is at once shut down; it is impossible to run the pump unprimed.

However, in the case of pumps driven by motors of low starting and "pull in" torque, special provision can be made for starting before priming, in which case De Laval pumps can be adapted for starting unprimed.

Where two or more pumps are near together, the different pumps in the group can have different suction lifts, as each pump, once primed, is isolated from the central vacuum reservoir. However, where water is drawn from wells it is usual to connect a chamber in the suction line to permit separation of air and settling of sand before the water passes to the pumps and all pumps served by the system will have the same constant submergence, thereby avoiding surges.

With pumps for liquids carrying solids in suspension, such as sewage or paper stock, the suction main is extended vertically above the pump suction to a level not reached by the liquid. Should the level in the submerged chamber drop to a certain point through accumulation of gases, the vacuum pump is started, and should it drop still lower the main pump is shut down until the excessive inleakage of air, or other trouble, is corrected.



Single pump fitted with priming unit.

The De Laval Submerged Suction Priming System is protected by patents and is available only for use with De Laval pumps.

For further particulars see Publication M-16, sent upon request.

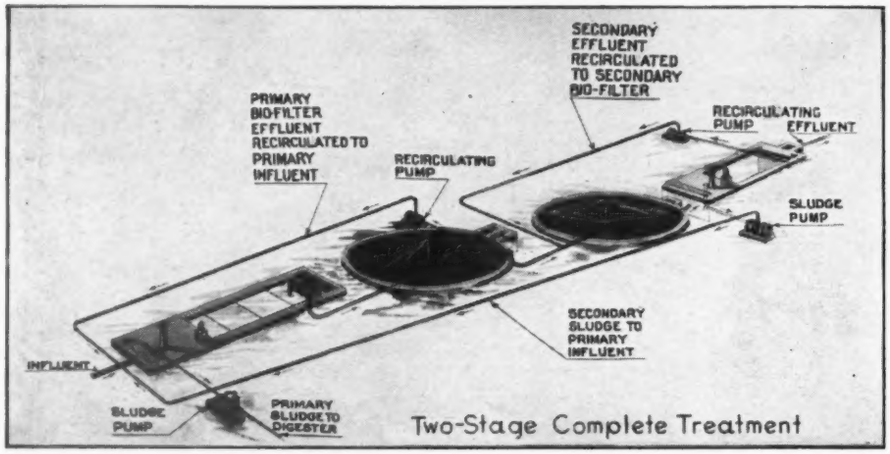
DE LAVAL STEAM TURBINE CO. . . TRENTON, N. J.

Visit our Booths Nos. 18 and 19 at the Royal York Hotel, Toronto, Ont., during the 61st Annual Meeting of the American Water Works Association, June 22 to 26, 1941

LINK-BELT *Sludge Collectors*

ASSURE BEST RESULTS FROM

BIO-FILTRATION SEWAGE TREATMENT!



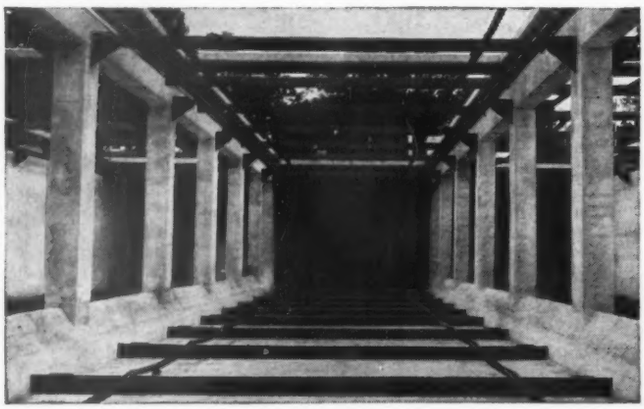
● Much of the effectiveness of this system depends on the reactions between the filter effluent and the raw or partly treated sewage in primary and secondary detention tank or tanks. Rectangular tanks equipped with Link-Belt STRAIGHTLINE collectors and circular tanks with CIRCULINE collectors for larger installations, are ideal for use with this process. Many Biofiltration plants now in service are proving the efficiency of Link-Belt Collectors with this system. Send for special Folder No. 1881.

SINGLE-STAGE COMPLETE TREATMENT

This treatment consists of primary settling, biological treatment in a sprinkling filter and secondary settling. Part of the flow from the filter is returned to the primary tank influent. The sludge from the secondary settling tank can be returned to the primary influent or go direct to the digestion tank. The B.O.D. of the effluent from the secondary tank is generally equal to that of a standard filter.

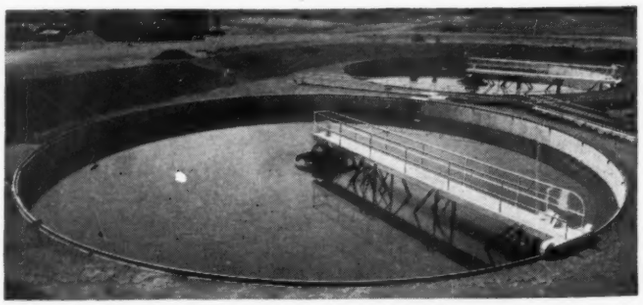
TWO-STAGE COMPLETE TREATMENT

This treatment has primary settling, series filtration and secondary settling. The effluent from the primary filter and the sludge from the secondary tank is returned to the primary tank. Part of the effluent from the secondary tank is recirculated to the secondary filter. This arrangement has exceptional flexibility, and strong domestic sewage or trade wastes can be successfully handled by such a plant.



← STRAIGHTLINE COLLECTORS

Link-Belt STRAIGHTLINE Sludge Collectors for the removal of sludge from rectangular settling tanks consist of two strands of especially processed malleable chain from which are suspended at uniform intervals scraper flights usually made from red wood. Features are peak-cap bearings, pivoted flights, cross collectors for larger tanks, and positive sludge removal at a slow, uniform speed. Automatic or semi-automatic skimming equipment is furnished when required. Send for Book No. 1742.



CIRCULINE COLLECTORS →

Link-Belt CIRCULINE Collectors for the removal of sludge from round tanks consist of a flight conveyor suspended from a bridge, one end of which is pivoted at the center and the other travels around the circumference of the tank. Features are positive slow uniform speed, positive sludge removal and excellent distribution of flow throughout the tank. Automatic skimming is furnished when desired. Send for Book No. 1642.

LINK-BELT COMPANY

Specialists in the Manufacture of Equipment for Water and Sewage Treatment Plants

Philadelphia · Chicago · Cleveland · Indianapolis
Los Angeles · Toronto · Offices in principal cities

8560

LINK-BELT

SCREENS · COLLECTORS · AERATORS · GRIT CHAMBERS · MIXERS

That EXTRA Something

YOU'LL NOTICE IT THE DAY YOU START USING THESE

Acclaimed ACTIVATED PRODUCTS

•

STANDARD ACTIVATED ALUM
ACTIVATED BLACKALUM
CHAMPION ACTIVATED CARBON
CHLORINATED BLEACHING CLAY
PALMER FILTER BED AGITATORS
LABORATORY STIRRERS

Their dependability of performance is traditional... is it any wonder that these fine products are ***BEING ENTHUSIASTICALLY RECEIVED*** by the waterworks profession . . . ***EVERYWHERE ?***

Everybody Likes Activated Alum

May we remind you again that we are exclusive agents for the Tate Pipe Lining Process . . . the rejuvenation treatment which will restore, preserve and even increase the carrying capacities of your pipe lines for years to come.

Activated Alum Corp.

Office
5701 Pennington Ave.
Baltimore, Md

Works
Curtis Bay
Baltimore, Md.

LEADITE

Trade Mark Registered U.S. Pat. Office

The Pioneer Self-Caulking Jointing Material for Bell and Spigot Water Pipe

Products

LEADITE and the following tools and equipment for use with LEADITE:

BRAIDED JUTE, JOINT RUNNERS, GASOLINE and WOOD BURNING MELTING FURNACES, POURING LADLES, POURING POTS, YARNING IRONS and METAL POURING GATES.

Description

Leadite is principally used for making joints in cast iron bell and spigot water mains; is shipped in powder form in sacks containing 100 pounds.

Users

Water works superintendents, engineers, contractors, mines, railroads and industrial plants all over the world use Leadite. Thousands of miles of pipe jointed with Leadite are in service.

Method of Use

The joint space is first "yarned" and the Leadite is melted and poured into the joint, but requires no caulking. Leadite melts at approximately 250° F. Lead melts at approximately 620° F.

Comparative Quantities

One hundred pounds of Leadite are equivalent to approximately four hundred pounds of pig lead based on the joints being made the same depth with either material. It will be easy to figure the approximate quantity of Leadite required for any given quantity of pipe by referring to our Reference Table, copy of which we shall gladly send to you upon request.

Comparative Cost

Under normal conditions, the economies effected by the use of Leadite save approximately 50% to 75% over the method which requires caulking, owing to the saving effected in material and labor.

Saving

Because Leadite saves on the items of caulking charges, digging of large bell-holes and reduces cost of trench pumping to a minimum, Leadite eliminates most every superfluous operation in jointing cast iron water mains, thus permitting the work to be completed with the least amount of effort.

Tools

As no caulking is required, fewer tools are needed.

No Caulking

Leadite joints require no caulking because Leadite adheres to the pipe from the yarn or jute out to face of bell, making a watertight bond. However, a Leadite joint may be melted or cut out at any time if desired in making connections, etc.

Durability

Leadite has been tested and used for more than 35 years and experience has proven that Leadite joints improve with age.

Expansion and Vibration

Leadite is used with excellent results under railroad tracks, highways and over and under bridges where severe vibration has demonstrated the value of using Leadite on this class of work.

Utility

Leadite is very easy to handle. It is used on all sizes of pipe from four to eighty-four inches in diameter and under all conditions and pressures encountered in water works construction.

Electrolysis

Leadite resists electrolysis.

Damage Suits

Claims for damages caused by joints blowing out are reduced because Leadite joints, if properly made, will not blow out under any pressure common in water works construction.

Transportation

Considerable freight charges are saved because Leadite is light in weight. This also means a saving in cartage and handling on the work because you move approximately one-fourth the weight of jointing material.

Delivery

We make prompt shipments of Leadite in any quantities from stock.

Fuel

Saves fuel because you melt approximately one pound of material instead of four, and less heat is required to melt Leadite than is needed to melt lead.

Be sure it is Leadite and not something "Just as Good"

THE LEADITE COMPANY

Girard Trust Company Bldg., Philadelphia, Pa.

No Caulking

PLAN TO SEE THE EXHIBIT OF THE

BADGER METER MFG. CO.

AT THE 61st ANNUAL MEETING

AMERICAN WATERWORKS ASSOCIATION

TORONTO · ONTARIO · CANADA

JUNE 22-26

MEASURES THE WATER OF THE WORLD

BADGER

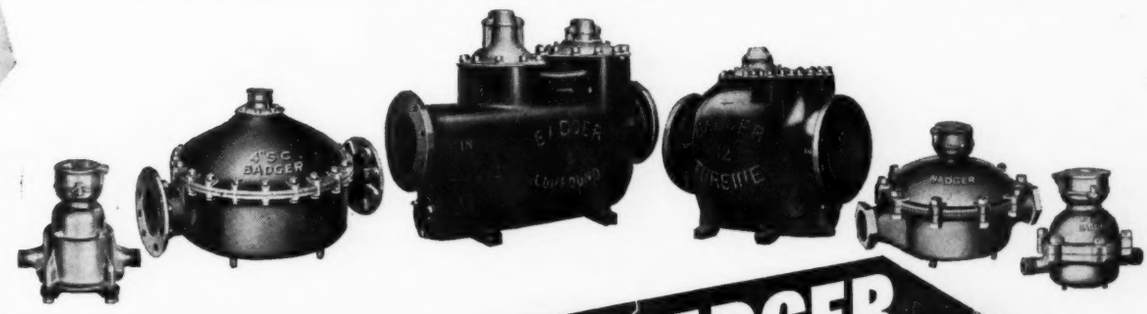
A SIZE AND TYPE FOR EVERY WATERWORKS SERVICE

Badger Meters have been measuring the waters of the world for more than a quarter century—they have pioneered higher accuracy standards.

There is a size and type of Badger Water Meter for every service—for reliable recording of the smallest stream to the heaviest flow—ranging from the ⅝″ disc to the large 10″ compound and 12″ turbine. Write for bulletins.

BADGER METER MANUFACTURING COMPANY · *Milwaukee, Wisconsin*

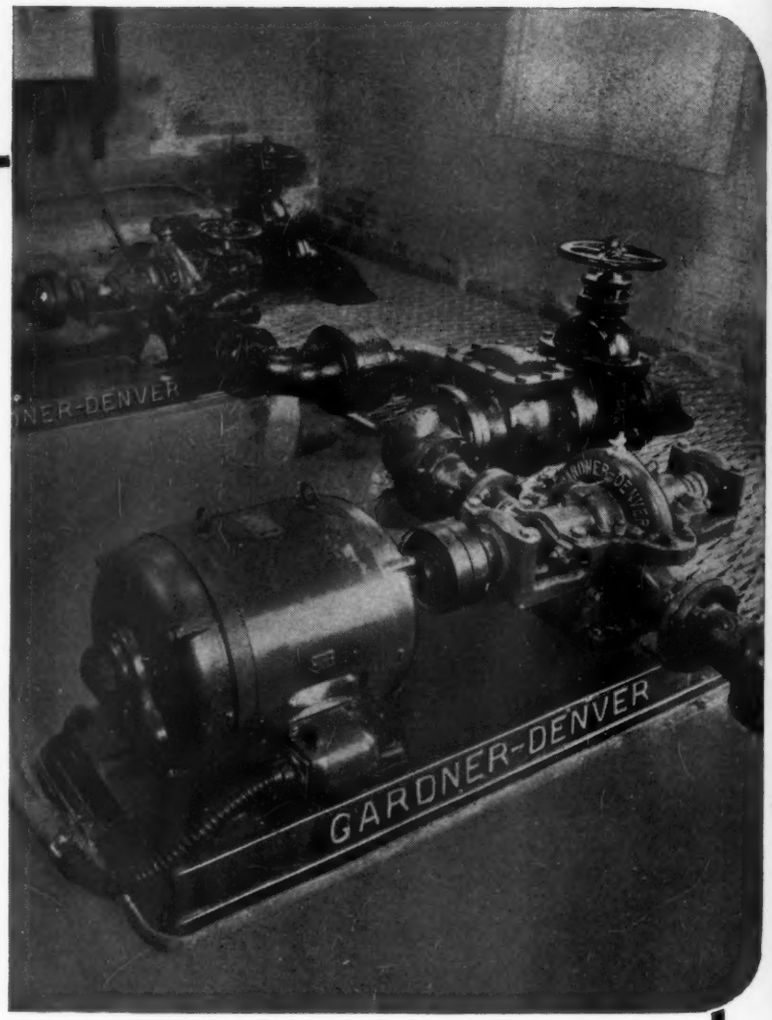
Branch Offices: New York City • Tampa, Fla. • Seattle, Wash. • Savannah, Ga. • Kansas City, Mo. Marshalltown, Iowa • Los Angeles, California • Chicago, Illinois • Waco, Texas • Philadelphia, Pa.



DURABILITY
DEPENDABILITY
SENSITIVENESS
LOW COST MAINTENANCE

BADGER *Water* METERS

THE CASE of the THANKFUL TAXPAYERS!



- *"Pumping 1,650,000 gallons per day... Gardner-Denver centrifugal pump exceeds rated capacity by 125 gallons per minute."*
- *"Our Diesel driven Gardner-Denver centrifugal pump operates at a power cost of only 12 cents per hour—saves $2020 per year."*
- *". . . 3000 gallons pumped for one cent by our Gardner-Denver centrifugal pump."*
- *"... the specified efficiencies of 88% were easily met in actual operating tests."*
- *". . . power costs: $6.00 per million gallons pumped by Gardner-Denver centrifugal."*

● No wonder taxpayers in so many cities and towns are thankful when Gardner-Denver centrifugals are installed. No wonder waterworks engineers praise the ability of these Horizontally-Split Case Centrifugal Pumps to reduce cost per thousand gallons pumped. It's their modern hydraulic design—their improved mechanical advantages—that enable these pumps to step up pumping efficiency and lower power costs.

Find out how these Gardner-Denver Centrifugal Pumps can save taxpayers' dollars in your city. Full information and specifications will gladly be sent on request. Write Gardner-Denver Company, Quincy, Illinois.

GARDNER-DENVER
Since 1859

ZECO and HI-ZECO Greensand Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

★

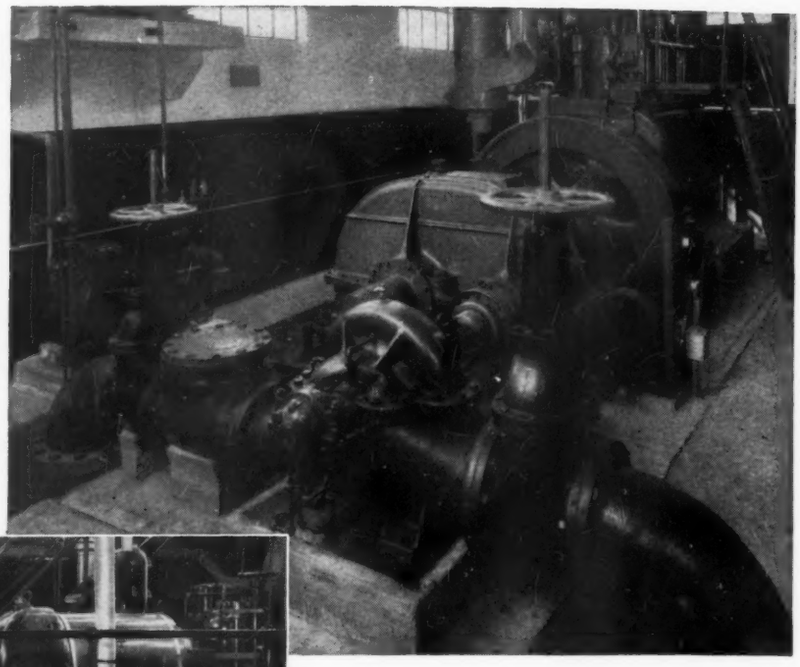
ZEOLITE CHEMICAL CO.

Sales Office
140 Cedar St., New York, N. Y.

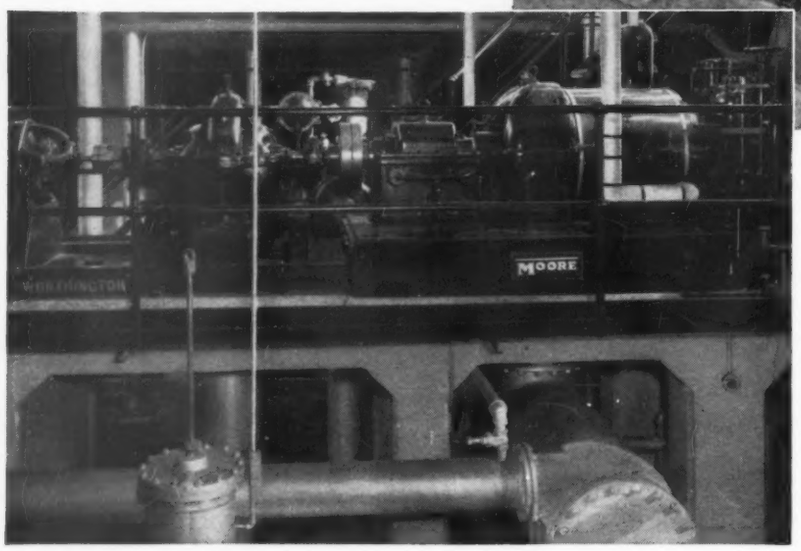
Factory
Medford, N. J.

Pioneer Producer of GREENSAND ZEOLITE MINERAL

A COMPREHENSIVE SERVICE *for* WATER SUPPLY



Serving the City of Meridian, Mississippi, this Worthington pumping unit was engineered and installed by A. M. Lockett & Co. Ltd., New Orleans, and delivers 5,000,000 gallons per day against a total head of 225 feet. It is driven by a Worthington 260 horsepower gas engine which requires less fuel gas for its operation than is needed to keep the old steam plant hot.



At the Hackensack (N. J.) Water Company's New Durham Station (shown at the left) this Worthington pumping unit is used for economical booster operation with capacities varying from 2,000,000 to 8,000,000 gallons per day against heads up to 162 feet. The 307 hp. Worthington-Moore geared steam turbine exhausts into a high vacuum Worthington condenser equipped with a Worthington two-stage steam air-ejector. The condensate pump is driven by a water turbine supplied with water from the main pump. The circulating pump is driven by the main turbine and is mounted on a small D.C. generator incorporated in the unit to furnish current for station lighting. All pumps and the water turbine are also by Worthington.

CENTRIFUGAL PUMPS
STEAM AND POWER PUMPS
TURBINE WELL PUMPS
SUMP AND DRAINAGE PUMPS
DIESEL ENGINES
GAS ENGINES
CONVERTIBLE GAS-DIESEL ENGINES
STEAM TURBINES
STEAM CONDENSERS
CONDENSER AUXILIARIES
FEEDWATER HEATERS
STEAM-JET EJECTORS
WATER PURIFICATION EQUIPMENT
STATIONARY AIR COMPRESSORS
PORTABLE AIR COMPRESSORS
ROCK DRILLING EQUIPMENT
CONSTRUCTION AIR TOOLS
V-BELT DRIVES
AIR LIFT SYSTEMS
WATER METERS

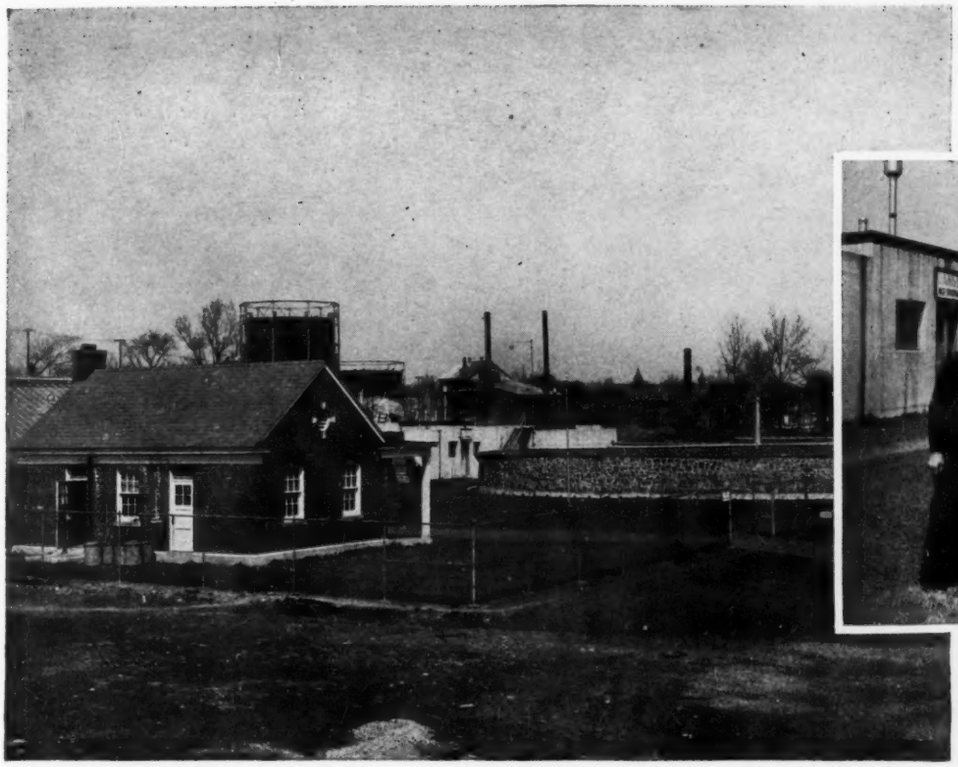
THESE two modern Worthington water works installations are but representative of the hundreds which are efficiently serving progressive municipalities throughout the country.

Worthington equipment for water supply comprises a most comprehensive line... not only main units of every type and size, and for every type of drive, but all auxiliary equipment... ***a complete service with undivided responsibility.***

WORTHINGTON PUMP AND MACHINERY CORPORATION
General Offices: **HARRISON, NEW JERSEY**
Branch Offices and Representatives in all Principal Cities

WORTHINGTON

CP1-3



Plan to attend 61st meeting of A. W. W. A.— Toronto, Ont., June 22nd—26th.

G. L. Palmer, Superintendent

Stroudsburg, Pa. USES MATHIESON CHLORINE AND HTH *for sewage treatment*

"(And)... we are completely satisfied," says Gilbert L. Palmer, Superintendent

Mathieson Chlorine and HTH have been used in this modern sewage treatment plant at Stroudsburg, Pa. since the plant was first put in operation in 1937. Both products have been used continuously since that time... rendering "completely satisfactory" service. Mathieson Chlorine for post-chlorination and HTH in the dosing chamber for the elimination of filter flies—also for regular dosing of the beds.

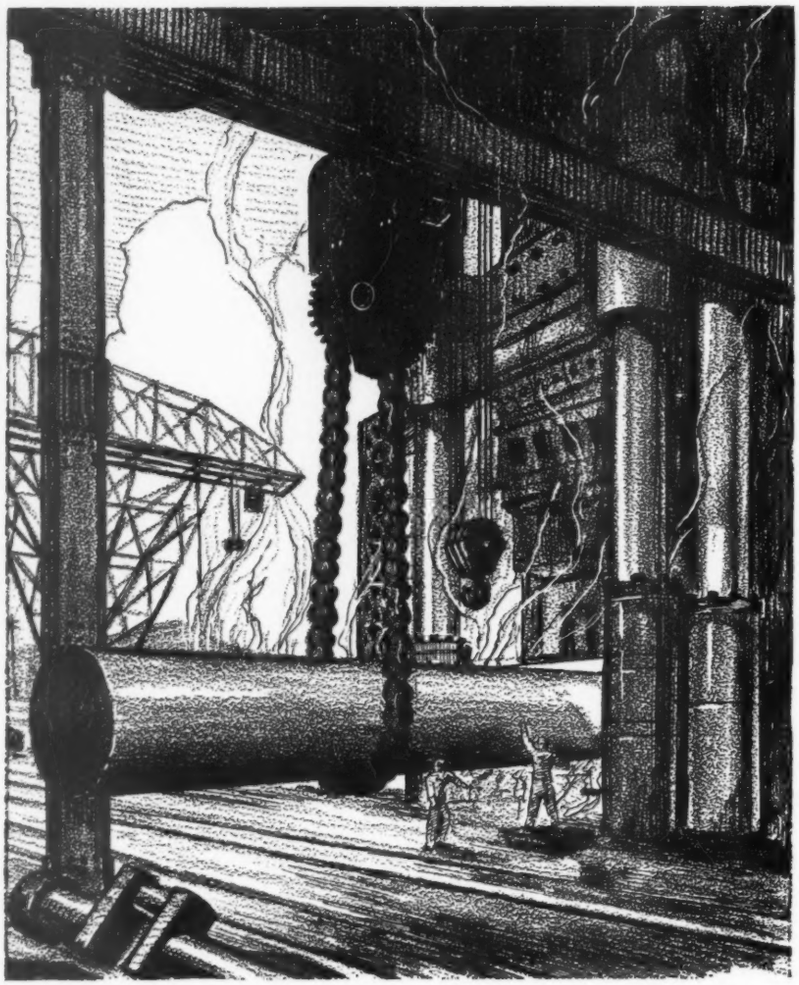
Satisfactory service is an old story to Mathieson Chlorine and HTH. Stroudsburg is only one of hundreds of cities and towns that find Mathieson sanitation service both dependable and efficient. In Mathieson Chlorine you get *pure* chlorine and prompt delivery in well kept, trouble-free containers. HTH, also, in addition to its use on everyday sanitation jobs, should be kept on hand for quick emergency service requiring a mobile, high-test chlorine carrier.

Write us for full information on Mathieson Chlorine and HTH.

HTH comes in 5-lb. cans with replaceable caps, packed 9 cans to the case; also in 100-lb. drums.

THE Mathieson Alkali Works (INC)
60 E. 42ND ST., NEW YORK, N. Y.

LIQUID CHLORINE . . . HTH . . . SODA ASH . . . CAUSTIC SODA . . . BLEACHING POWDER . . . AMMONIA, ANHYDROUS and AQUA . . . BICARBONATE OF SODA . . . PH-PLUS (FUSED ALKALI) . . . DRY ICE . . . CARBONIC GAS . . . SYNTHETIC SALT CAKE . . . SODIUM CHLORITE PRODUCTS



Seven Ordnance Plants are now being constructed, employing four P.F.T. Floating Cover Digesters, six Rotary Distributors, five Siphons and numerous items of Boiler Room Equipment.

On over sixty National Defense Projects — Ordnance, Army, Navy, Aviation—safe sanitary measures are provided by P. F. T. Sewage Treatment Plant Equipment.

These installations are fitted with the following P. F. T. Equipments:

- ★ *54 Floating Cover Digesters*
- ★ *13 Rotary Distributors*
- ★ *46 Siphon Installations*
- ★ *18 Sewage Sludge Pumps*
- ★ *44 Boiler Room Installations using: Flame Traps, Pressure Relief Flame Traps, Waste Gas Burners, Gages, Drip Traps, etc.*

The preference for equipment of P.F.T. design and manufacture by consultants in the field and engineers at headquarters is acknowledged with pride. It comes, we feel, as our reward for almost half a century of specialization in doing one thing well.

We are glad to serve in the cause of National Defense and hope that our small efforts will in some way aid in quickly reaching the desired goal — peace!

P.F.T *Pacific Flush-Tank Co.*
4741 RAVENSWOOD AVENUE, CHICAGO
NEW YORK CHARLOTTE, N.C.

World's Largest Exclusive Manufacturers of Sewage Treatment Equipment Since 1893

BUILDERS *Water Works Meters and Controllers*

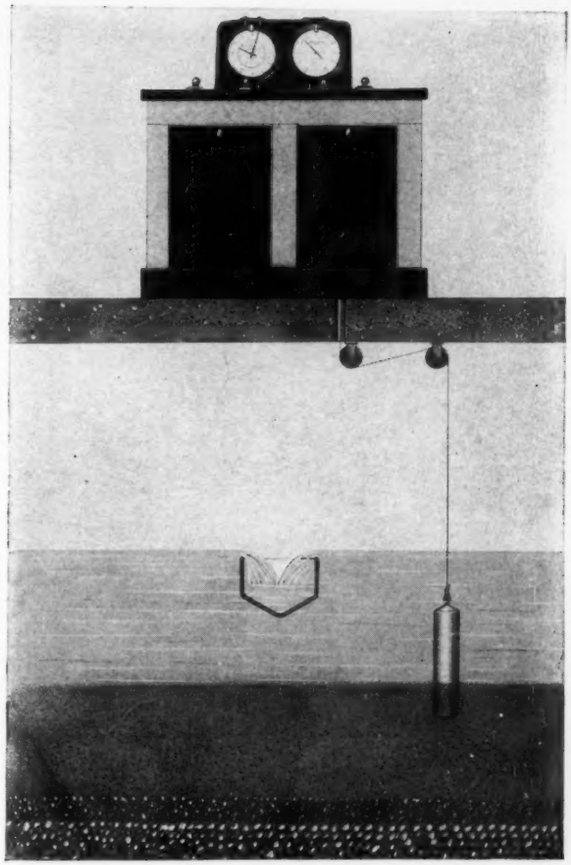
NEW—Builders Sand Expansion Gauge—

Shows % Sand Expansion in Filter Bed—High-Torque principle assures accuracy—Displacer combines power and stability—Adjustable for individual filters.

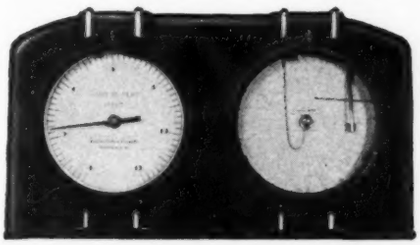
In the modern rapid sand filtration plant, adequate and efficient back washing of the filters is essential to a continuous supply of potable water. Troubles that overcome filters, such as mud balls and fissures, often can be traced directly to some shortcoming in the washing procedure. The washing process not only should be thorough, but it should also be efficient if operating costs are to be conserved. Several methods of wash control have been devised; prominent among them is the use of a Sand Expansion Gauge.

Builders Sand Expansion Gauge enables the operator to control both the *extent* and the *rate* of sand expansion in the filter bed. It operates independently of changes in wash water flow, pressure or temperature. Indicators and Recorders can be furnished in standard attractive designs for table or floor stand mounting. Large Indicators, 24″ and 30″ diameter, with white gas-tube illumination, are available for wall or ceiling mounting, using Chronoflo transmission between filter and Gauge.

See this new Gauge in operation at Toronto—or write for Bulletin 335.

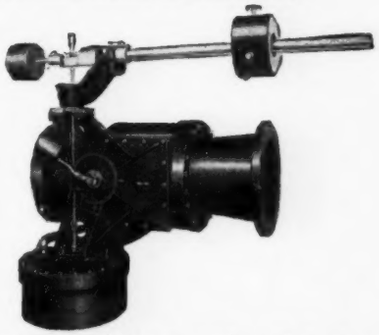


Builders Gauges for Water Works



Builders Gauges are installed in hundreds of filter plants in the United States and Canada. Simple in operating principle, they are styled to harmonize with the attractiveness of modern filtration plant interiors. Ask for Bulletin 329.

Builders Filter Effluent Controllers



Venturi Direct Acting, Type E, Controllers feature precise control; low loss of head; rigid balanced valve; compact, yet flexible design; powerful "floating piston" actuation; and the exclusive molded, tapered "piston" seal. Ask for Bulletin 321.

A.W.W.A. CONVENTION TORONTO · JUNE 22-26 BOOTHS 85-86

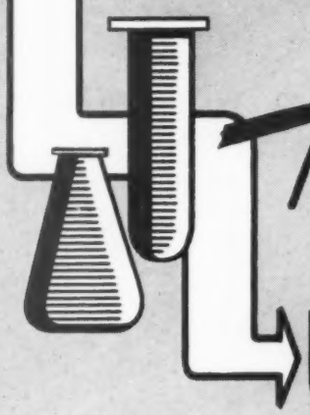
BUILDERS - PROVIDENCE, INC.

(DIVISION OF BUILDERS IRON FOUNDRY)

PROVIDENCE . . . RHODE ISLAND

CHEMICAL TREATMENT of SEWAGE
MUNICIPAL PLANT TESTS*

	Coagulant	Dosage	Percent Reduction		Total Cost Per M.G.
			Suspended Solids	B.O.D.	
EXAMPLE NO. 1	Alum	2.0 g/g	72.8	57.7	$3.32
	Alum and Sodium Silicate	0.2 g/g SiO_2 +1.5 g/g Alum	84.0	75.5	$3.85
EXAMPLE NO. 2	Copperas and Sodium Silicate	0.4 g/g SiO_2 +1.7 g/g Copperas	70.4	68.6	$2.27
	Chlorinated Copperas	2.9 g/g	51.9	51.8	$3.27



These figures say

USE SODIUM SILICATE
for BETTER RESULTS . . . LOWER COSTS

As shown by the data above, STANDARD SILICATES open a roadway to more effective sewage treatment at lower costs. Used in combination with other chemicals, Sodium Silicates give a higher percentage reduction of suspended solids and B.O.D. at a low cost.

Let the Diamond Technical Staff help you apply STANDARD SILICATES to your needs.

*From *Sewage Works Journal*, November, 1940

DIAMOND ALKALI COMPANY • Standard Silicate Division

Plants at CINCINNATI · JERSEY CITY
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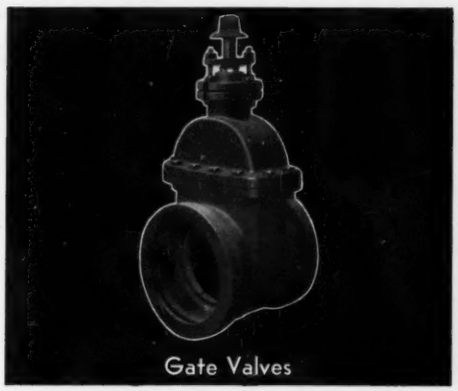
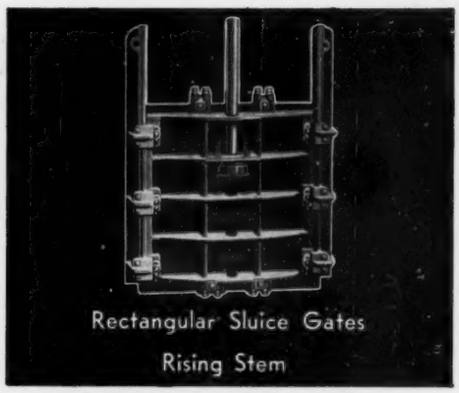
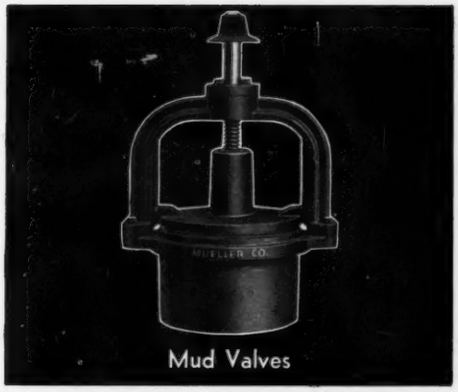

Gate Valves


Rectangular Sluice Gates Rising Stem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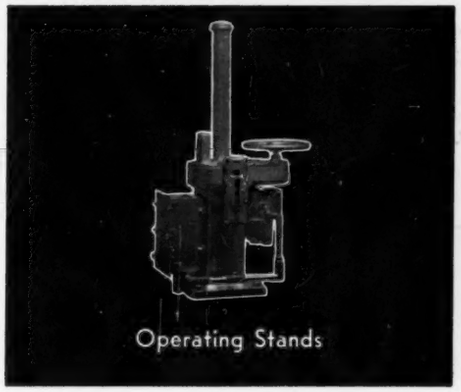
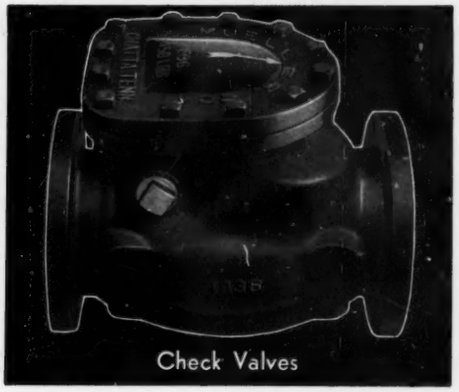

Operating Stands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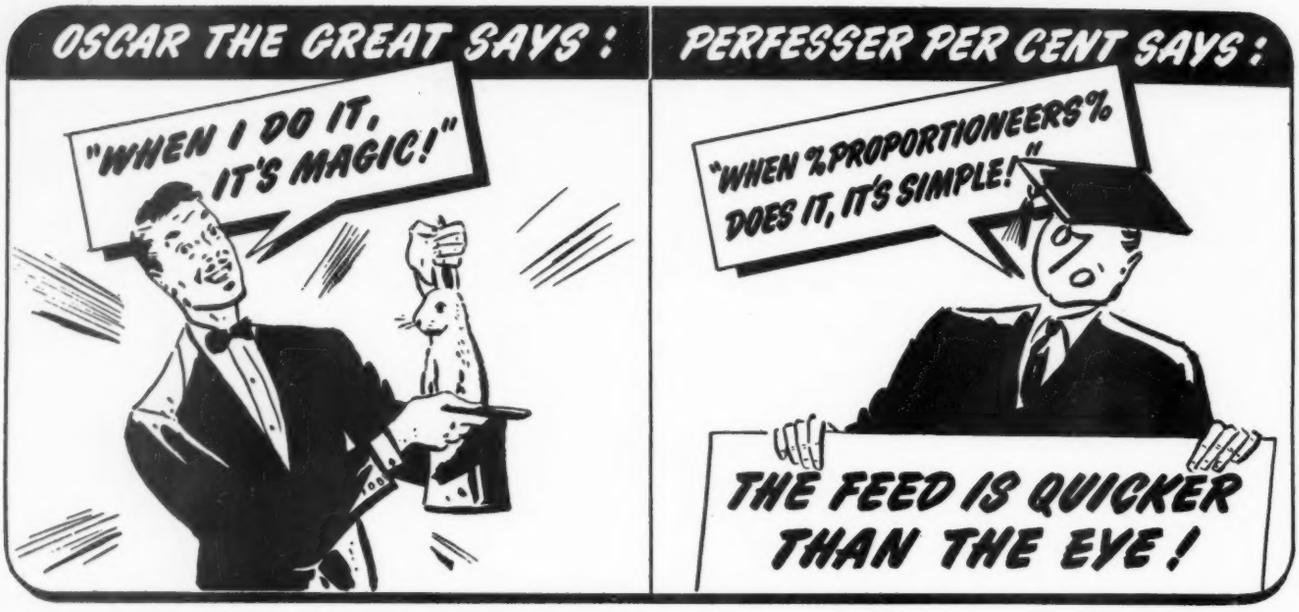
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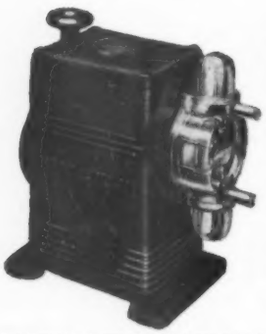

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WATER WORKS & SEWERAGE

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COMING!

"Some Pertinent Considerations in Water Corrosion and Corrective Measures."

Constitute the basis for interesting disclosures by a chemist and engineer who has made a careful study of the chemical make-up of a number of waters, and of varied quality, in relation to practical observations on the condition of mains and service pipes carrying these waters. The author presents a new thought for consideration in evaluating or predicting corrosivity of waters. He suggests a procedure for readjusting the hardness alkalinity balance upset by the refining process of coagulation and filtration, which seems to be an underlying cause for the general observation that filtered waters are pronouncedly more corrosive and tuberculating than unfiltered waters. This thought provoking discussion comes from—

THOMAS R. RIDDICK,
Consulting Engineer and Chemist,
New York, New York

"Industrial Waste Treatment Practices."

A series of articles to reveal progress in pollution abatement by the petroleum products industry and methods developed for treating petroleum production and refining wastes has already been begun by W. B. Hart and associates of the Atlantic Refining Co. The next article has been planned for our July issue.

In this direction we have been very fortunate in arranging for a valuable series of articles dealing with treatment of various types of wastes by a man of considerable experience in this phase of pollution abatement. Tanning, milk products, meat packing, canning, gas house, laundry and textile wastes, are amongst those to be covered. This authority has figuratively lived with industrial waste treatment for the past several years. He is—

E. F. ELDRIDGE, Research Associate,
Michigan Engineering Experiment Sta.

"Meter Testing Experience and Practice."

As developed in the St. Louis Water Department, is based on knowledge gained in a study applied to test methods, equipment and routine practices. The result is a modernly equipped shop and sound practice based on scientifically established grounds. In this issue is an article by D. R. Taylor on field-testing of important meters, and the St. Louis story is a splendid companion article, dealing with shop practices. The author—

ROBERT M. BELL, Civil Engineer,
Division of Water, St. Louis, Mo.

"The Oxidized Sludge Process—Equilibrium Index."

Is described in a paper that we believe will attract much interest. It reports new theories inherent in the Activated Sludge Process mechanism, and discloses the amenability of this mechanism to precise mathematical control. In the final analysis the "Oxidized Sludge Process" is revealed as a very simple mechanism, reported capable of absorbing varying loadings and transient overloads without upset. Conventional test methods and equipment have been discarded in favor of a simple method of determining the condition of the process, through the "Equilibrium Index." Records of two years of performance of a previously ungovernable municipal plant are presented in support of the efficacy of this method. The author and inventor, who claims that the specter of sludge bulking, need be no more, is—

EDWARD B. MALLORY, Director,
Lancaster Research Laboratories,
Hackensack, N. J.

"Basic Factors Affecting Pollution of Sub Surface Waters."

Is a well written discussion of those factors which singly or combined are responsible for the pollution or the safety of sub-surface waters. The author has done a good job of reviewing the picture of ground water supplies and considerations which the water works operator should understand if safe maintenance and operation of wells is to be assured. This contribution comes from—

L. C. MacMURRAY, Ass't Engineer,
Maryland State Dept. of Health.

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H. P. GILLETTE, President; E. S. GILLETTE, Vice Pres. and Publisher; L. H. ENSLOW, Vice Pres. and Editor; JOHN C. BLACK, Managing Editor; Associate Editors — J. R. BAYLIS, A. M. RAWN, H. A. FARR; H. J. CONWAY, Make-Up Editor; D. G. LEDGERWOOD, Advertising Editor.

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The SYMBOL of SUSTAINED ACCURACY

From a drawing by his son—Alan Howard

An Editorial

by

NORMAN J. HOWARD

Guest Editor

PRESIDENT OF THE
AMERICAN WATER WORKS
ASSOCIATION

Norman J. Howard

WHAT DOES IT TAKE TO MAKE A SUCCESS IN WATER WORKS OPERATION?

IT IS DOUBTFUL if the services of any official in the public utility field, notably those engaged in or responsible for the production and maintenance of water supply, receive either adequate remuneration or recognition by consumers. This is due in part to disinterestedness and lack of appreciation of the immensity of water supply problems. The average water works official is a notoriously poor salesman. His work is often only publicized when some problem of supply arises. This may include interruption of service, questions of quality or some phase involving physical characteristics or palatability.

As previously mentioned, the average consumer is rarely interested in water works personnel until trouble arises, but when it does, abuse and claims of incompetency are the invariable outcome. All of which leads up to the question under consideration. What are reasonable modern day requirements for a successful water works operator and how can they be achieved?

In recent years determined efforts have been made to either license operators or to encourage their attendance at State conferences or short schools of instruction. The aims of both of these efforts has been for similar purposes, namely, first hand instruction on theory and practice. There are two distinct classes of operators—namely, those who have been privileged to receive technical training through recognized sources, and those who have grown up on the job and have obtained their experience through plant operation. We are primarily concerned with the last named grouping, because while the operation may usually be efficient, there are times when due to the lack of technical training, both costly and faulty operation may result.

The ambitious and go-ahead man is eager to assimilate knowledge in all branches of his work. He should be a good listener, always realizing that much valuable information can at times be gained by listening to the viewpoint of others less well informed than himself. Attendance when possible at all State courses will be valuable in securing technical training in both theory and practice, in meeting his fellow operator and learning not only how similar problems are handled but of securing details of new equipment, new methods of treatment and time saving devices.

And, one of the fundamentals of success, in these times, is to be able to speak in public without unduly boring the audience. This may seem superfluous to some water works men, yet an operator who can intelligently portray a picture of his work will command both support and confidence.

The visiting of water works plants in other locations will, generally speaking, be productive of much information of practical value. Membership in associations which publish scientific treatises and data, covering the entire water works field, will be found not only to be of great personal value but an additional means of securing information, and of keeping up to date with modern practice and progress. Again, attendance at the National convention of the American Water Works Association will bring the operator in contact with the leading engineers and sanitarians of the country. These men are not only willing and anxious to discuss their problems, but to suggest methods for more efficient plant operation and management.

The successful operator will invariably be found to be one who does not watch the clock, but who, should occasion arise, be sufficiently interested in his work to stay so long as it may be necessary.

Old methods, no matter how well maintained, must give way to new ideas should they be proven superior. Age must ultimately give way to youth, and the older operator must realize that he can best serve his community by recognizing this fact, and by instilling in his ultimate successor not only the essentials of economic and good operation, but the principles of obedience and loyalty. This is an age for youth to demonstrate his worth. Only by the dint of hard work can success be achieved.

These are days of specialization and efficiency, and those of incompetency or inefficiency are things of the past. Promotion is largely made on the basis of proven ability and achievement. Those who systematically work to improve their education and familiarize themselves with modern methods involved in operation will in the long run reap the looked for reward. Personality, and let me repeat again, the ability to meet the public and discuss problems in a language which can be understood, are amongst the essential factors of success.

Norman S. Howard

WATER WORKS & SEWERAGE

VOL. 88, NO. 6 *A Gillette Publication* JUNE, 1941

THE NEW WATERWORKS OF SPRINGFIELD, MO.

By L. R. HOWSON
Consulting Engineer*
CHICAGO, ILLINOIS

IT IS not often that a water works which has reached the mature age of 55 years builds entirely new pumping and treatment facilities. Yet this evidence of the Springfield City Water Co.'s confidence in the future of the community which it serves is but one of the interesting transitional phases of its development.

The original water works of Springfield was started in 1883, at a time when this city was a community of less than 15,000 people. The original source of supply was Fulbright Spring, located about 4 miles north of Springfield at a site which was then developed and utilized during the rainy season by a grist mill. A steam pumping station was installed at the spring, a force main laid to the city and at the north city limits, an earth reservoir was constructed to furnish close-in storage. Domestic and fire service were provided by a steam pump located at the reservoir, which pumped water from the reservoir into a water tower and the city distribution system, consisting of about ten miles of pipe serving 1,000 consumers. As the city grew, additional springs were developed until in all some four or five springs were commonly utilized during the dry season.

The Author
President-Elect
A.W.W.A.

*Of Alvord, Burdick and Howson, Engineers

New Filtration Plant and Pumping Station of the Springfield (Mo.) Water Co.
Boiler Room and Pumping Station, on left; Head House and Laboratory, in center; the Filters on right. An $850,000 *Investment in the Future of Water Supply.*

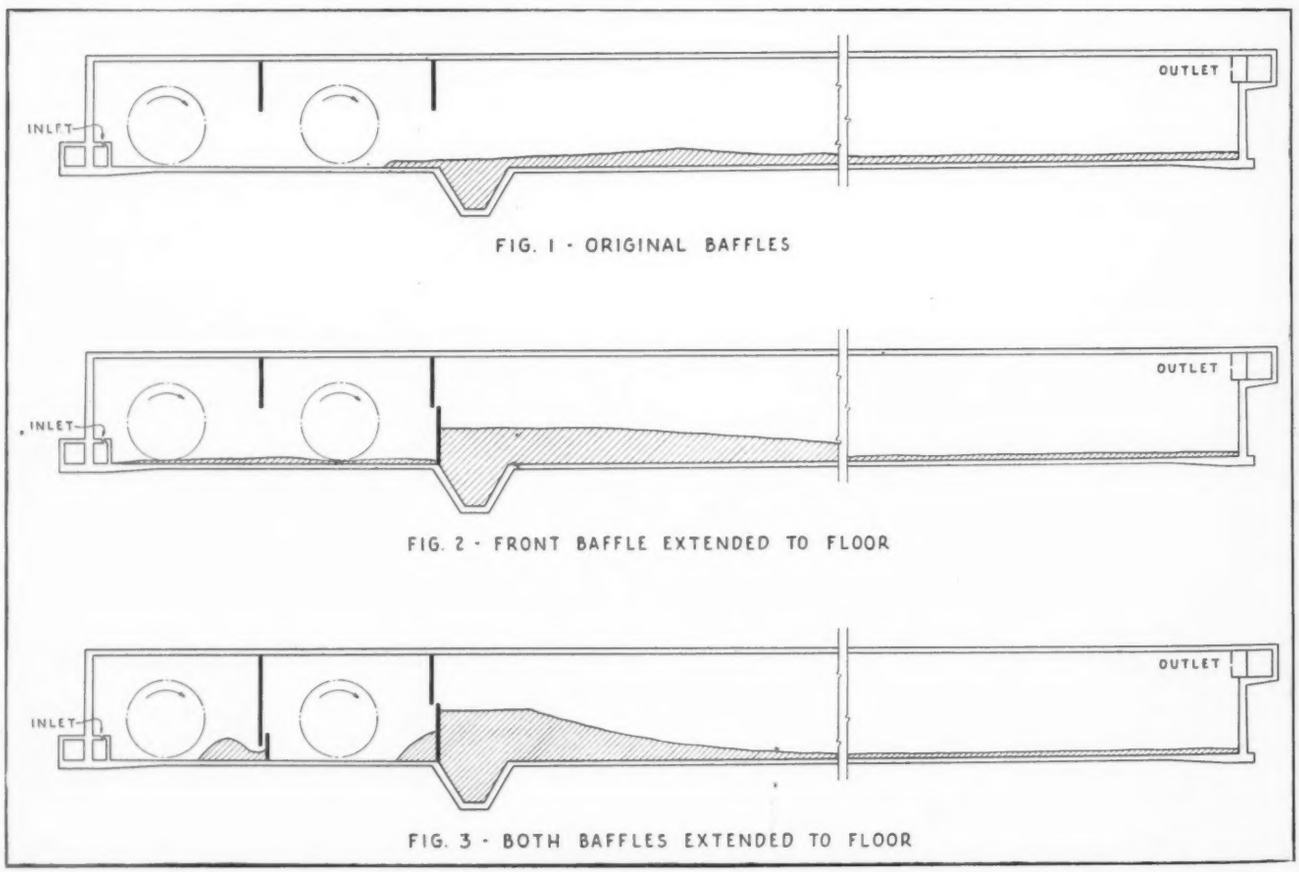
Interesting History (Including Discovery of a Natural Conduit)

Springfield is located in the cavernous limestone country. The flow of the springs varies widely as between wet and dry seasons. Accordingly, in 1892 it was decided to construct a dam about 4 miles east of Fulbright Spring, where there was another grist mill. It was noted that when this mill was running, the flow of water at Fulbright Spring was notably increased. After watching this for some time it was discovered that there was a subterranean passage just below the spillway of this grist mill, which led directly to Fulbright Spring, and it was definitely determined that when a certain quantity of water was released at the grist mill, the same quantity appeared at Fulbright Spring about 3 hours later. That discovery was very valuable to the City Water Co. It purchased the grist mill site and constructed there a concrete dam impounding about two months' supply. The use of the subterranean passage obviated the necessity of constructing a connecting pipe line at a cost of about $100,000. In fact, in a subsequent rate case a valuation of $100,000 designated as "water rights" was included in the rate base to cover the value of this nature-provided underground passage.

Even with the increased supply afforded by the Valley Mill's reservoir there were times when shortages were imminent. After a number of geological reports and investigations the company in 1915 drilled a 24-inch well to a depth of 1,404 feet, and was fortunate in securing the largest production thus far secured from any well drilled in the Ozark area. This well will deliver a sustained capacity of approximately 1,250,000 gallons per day. It is still in service, although not regularly used except during dry weather periods. Two other wells were drilled later but both have been abandoned.

Springfield continued to grow and its water requirements increased so that it became apparent in 1920 that an additional supply would be required. At that time a comprehensive investigation was made by Burgess & Niple of Columbus, Ohio, upon all practicable, available sources, including the James River, the Sac River, and other smaller water sheds. All of the water sheds within a reasonable distance of Springfield are of relatively small drainage area; this because Springfield is located at the summit of divides, from which the water flows in all directions. Also the finding of tight formations in the rock suitable for impounding reservoir construction is a difficult matter. Mr. Burgess selected a site on the little Sac River about 7 miles from Springfield.

After numerous geological investigations and reports the Water Company decided to build a concrete dam at that location. This dam was completed in 1930 and formed what is known as McDaniel Lake. The concrete dam is approximately 1,500 feet in length, 45 feet in maximum height, of a gravity type section with a spillway 420 feet in length, and storing approximately 1,150,000,000 gallons of water. The stream at that point has a drainage area of approximately 41 square miles. The safe yield of this reservoir is estimated at something in excess of 6 million gallons daily. It can be increased to at least 12 M.G.D. by raising the height of the dam.



For Improving Floc Subsidence in Springfield Basins
The Progressive Baffling Scheme Sketched.

Since this reservoir was completed, Springfield has experienced the two driest years of record, namely, 1930 and 1934, so that the data relative to safe yield is now much better than when the reservoir was first considered.

Easily collapsed flashboards have been installed to add approximately 300,000,000 gallons of storage at a cost of but approximately $2,000. The spillway is of such length and design that there is 5 feet freeboard over the crest with a foot walk available for flashboard installation and removal. The flashboards consist of planks 3 feet high, held by water pressure against vertical steel beams. During flood these beams can be "tripped" from the walkway above in such a way as to release the boards and thus permit the spillway to discharge the previously stored 3 feet together with the flood flow. An attendant is at the dam at all times.

The steam pumping station was continued in operation until about 1912. At that time a mechanical filtration plant of 6 M.G.D. capacity was installed. This filter plant has been in continuous operation until the last year when it was superseded in regular operation by the new plant which is described herein. This filter plant was of the conventional type of its day, provided with air and water wash, a short coagulating period, and a clear well having about a half million gallons storage.

Simultaneously with the construction of the filter plant in 1912, the pumping station was electrified, using 25 cycle current. This, too, was continued in operation until the new work was installed in 1939 and 1940. The old steam pumping station with two 5 M.G.D. pumps was continued in service as standby equipment during the twenty-eight years of operation of the electric equipment.

The New Construction Program

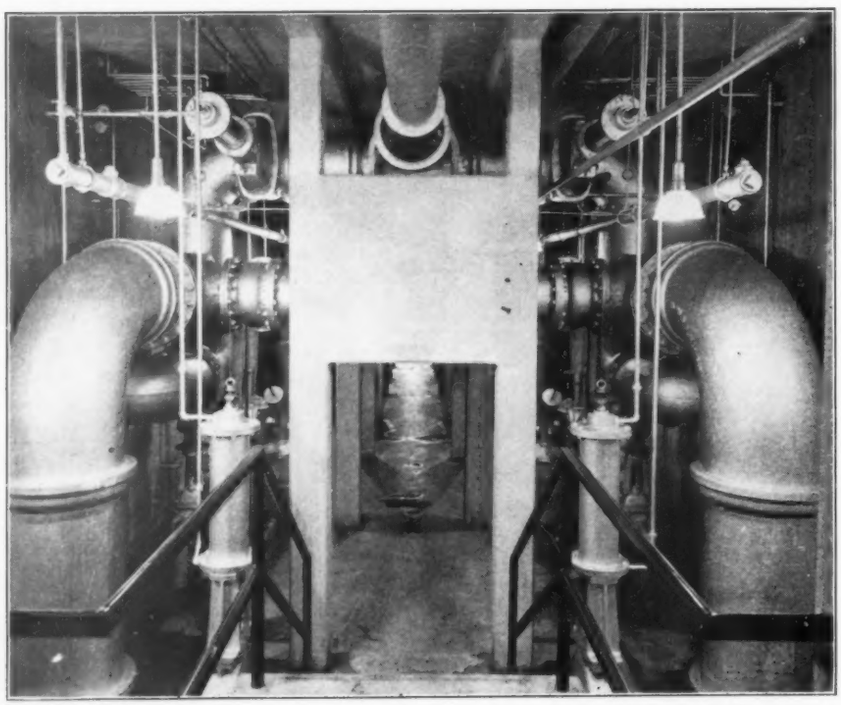
In 1936, Alvord, Burdick & Howson were employed to make a comprehensive investigation and report upon increased water supply and the most practicable procedure with respect to the future operations of the pumping station and filter plant. It was found that the Sac River was capable of increased development so as to meet the requirements at least as late as 1970; it also developed that it would be very difficult to enlarge the existing filter plant to meet the growing requirements. It was felt that a capacity of about 12 M.G.D. was needed to make reasonable provision for future needs. The old plant was so built as to be hemmed in on all sides and be practically incapable of enlargement. Rather than to have two 6 M.G.D. filter plants it was decided to build 12 M.G.D. in a single new plant.

The Filter Operating Gallery

Three 2 M.G.D. Units of the Central Gullet Type on Each Side. Note the Self-Supporting Roof of Pleasing Arch Design.

The Laboratory
Provides Boiler Water Control as Well as Purification Supervision.

It was also found that in view of the electric rate available and the remoteness of the water works plant from the electrical supply with the correspondingly greater necessity for standby or reserve equipment it was desirable to revert to the use of steam equipment. The remaining steam standby equipment was inadequate and it was accordingly decided to build a complete new installation consisting of a boiler plant, turbo pumping and generating equipment and a complete 12 M.G.D. filter plant with a 2 M.G.D. clear well. This work has now been completed and in operation substantially a year. Its cost was approximately $850,000.



The Pipe Gallery
Concrete Influent Conduit in Upper Center; Concrete Effluent Conduit Is Beneath the Filters. All Others of Cast-Iron and Hydraulically Valved.

Boiler and Pumping Plant

The boiler installation consists of two Stirling boilers, each rated at 252 H.P., operating under 275 pounds steam pressure and 100 degrees F. superheat. The boilers are equipped with forced draft chain grate stokers supplied from an overhead coal storage bunker. Coal is weighed to the stokers by a traveling weigh larry. Coal is brought to the station by truck and elevated to the overhead bunker. Average evaporation is 8.05 pounds of water per pound of coal.

Boiler water as well as the public supply is under careful laboratory control. The boilers have had nothing done to them except flushing with a hose when idle and are perfectly clean after a full year's operation.

The steam turbine equipment, a photograph of which appears with this article, consists of 4 units as follows:

A. One unit consisting of an 834 H.P. Westinghouse steam turbine driving through reducing gears, a 6 M.G.D. high lift pump and a 312 K.V.A. generator. The generator is installed to furnish power for operating the low lift pumps at McDaniel Lake approximately 3 miles away.
B. One unit consisting of a 1127 H.P. Westinghouse turbine driving a 9 M.G.D. Worthington centrifugal pump and a 375 K.V.A. generator.
C. An 860 H.P. Westinghouse steam turbine driving an 11 M.G.D. centrifugal pump.
D. A 500 H.P. Westinghouse steam turbine driving a 375 K.V.A. A.C. generator.

With this equipment the water works is entirely independent of outside power for all requirements at the station and also for low lift pumping from outlying stations. The installation provides a total high lift capacity of 26 M.G.D., or of 15 M.G.D. with the largest unit out of service for any reason. The equipment is of the most modern high speed geared type. The generator capacity provides for all low lift pumping from both the McDaniel Lake and Fulbright Spring supplies as well as liberal reserve. The equipment operates quietly as well as efficiently.

Purification

The filtration plant is rated at 12 M.G.D. when filtering at the rate of 2 gallons per square foot per minute.

The McDaniel Lake water is relatively soft; however, the Fulbright Spring and the other spring supplies are relatively hard. The plant accordingly has been designed so that softening equipment can be installed at a later date if that is found desirable.

Mixing and Flocculation

Raw water is pumped from McDaniel Lake about 3 miles from the filter plant through a 24-inch force main by electric motor driven centrifugals using power generated at the main plant. The raw water from Ful-

bright Spring is also pumped electrically. Water from the two sources is discharged to a rapid mixing basin and thence through two coagulating basins in parallel. The first part of each basin consists of a flocculating compartment, equipped with Dorr Flocculators, and providing approximately 40 minutes slow stirring period. After being flocculated the water flows into the quiescent settling compartment which provides a theoretical retention period of 3 hours when the plant is operating at designed capacity.

The character of the water normally treated in the new plant is such that the floc is quite fine even after such prolonged flocculation. Observation of the settling basin with particular reference to the depth of the deposits of sediment therein disclosed that the basins were not operating as efficiently as was planned. The three sketches show how a progressive improvement in settling facilities was accomplished.

Improved Settling

The first sketch shows the manner in which the sediment was deposited in the settling basin with the flocculator baffles as originally installed. After this observation was made it was decided to carry one baffle up from the floor until it overlapped the last suspended baffle. When this was done a marked improvement in the settling out and the distribution of sediment was observed as shown in the second sketch. Subsequently a bottom baffle was extended up from the floor to overlap the middle suspended baffle which is located between the two flocculator shafts and paddles. The results with this alteration were even more pronounced. While this type of baffling might not be required where a heavy floc was formed it has, as shown by the sketches, proven very beneficial at Springfield. The dropping out of the sediment near the drain hoppers greatly facilitates basin cleaning.

At the present time the turbidity going to the filters averages 1.5 p.p.m. and never exceeds 3 p.p.m. The turbidity of the raw water varies from quite clear to as high as 1,000 p.p.m.

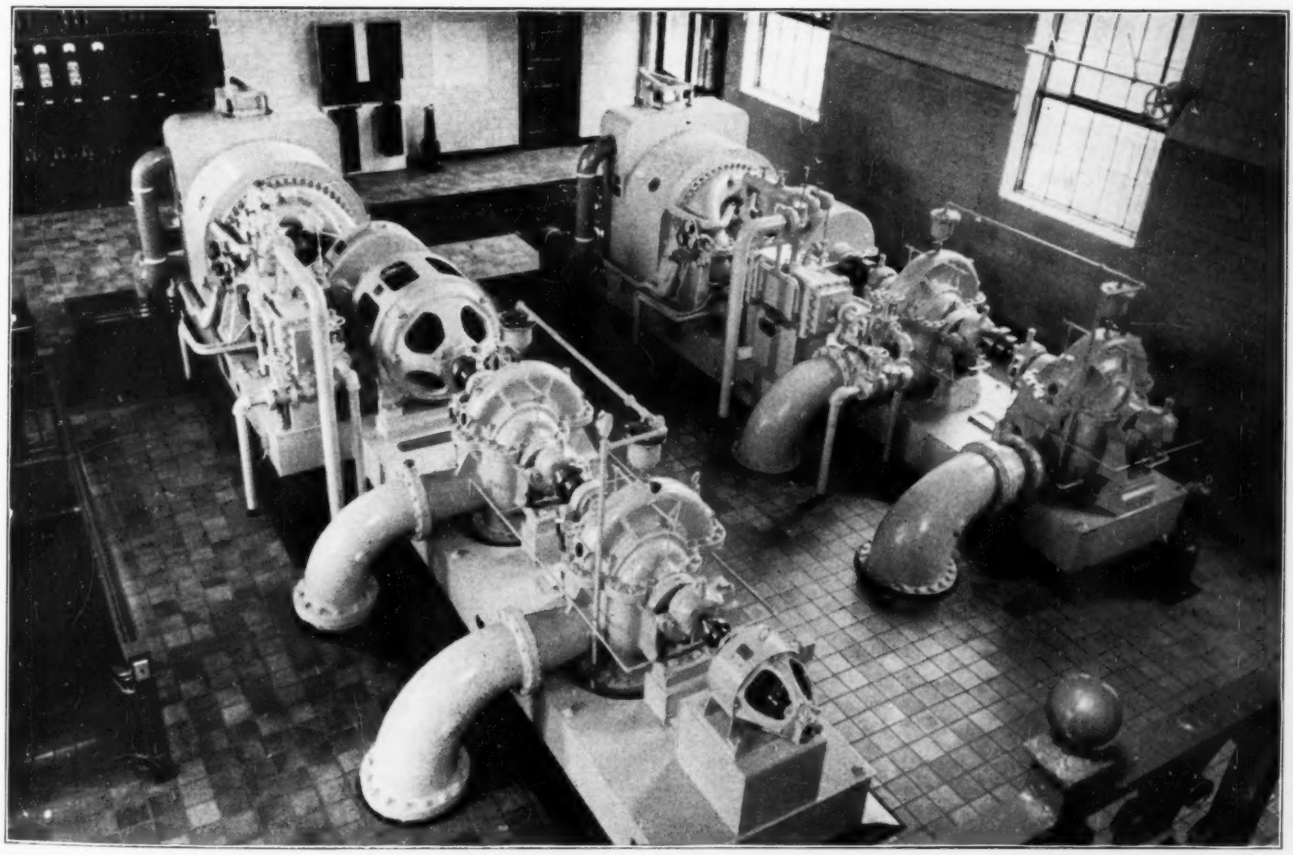
The settling basins have been designed for the installation of drag line clarifier equipment. However, installation of the equipment will be deferred until such time as softening is made a regular operation.

Uniform withdrawal of settled water from the settling basins is effected by its passage through a submerged slotted opening into a collecting trough.

The Filters

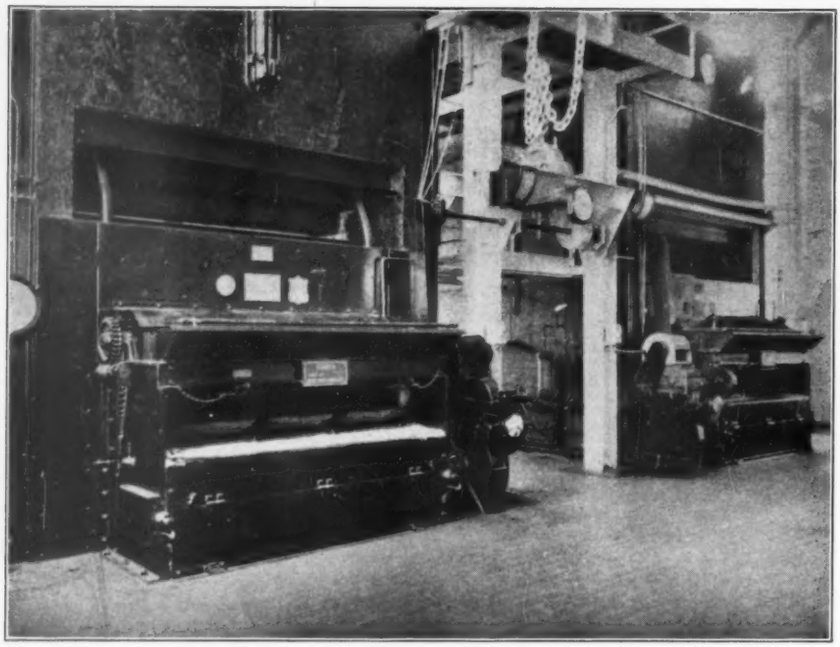
There are 6 filter units each of 2 M.G.D. capacity and of the central gullet type. Influent and effluent conduits are of concrete. All other piping is cast iron. (See cut of Pipe Gallery.) Hydraulic valves are used throughout. The underdrain system consists of 3-inch cast iron laterals located at 8-inch centers with ⅜-inch holes pointed downward at 6 inches on centers. The laterals are 11 feet 5 inches in length. They connect into the central gullet which is a two level structure, the lower compartment normally carrying the effluent, except during washing periods when it distributes the washwater to the laterals. The upper part serves as a collecting gutter for the dirty wash water.

The wash troughs are of concrete. There are two effluent conduits, one on each side, and each consisting of a concrete channel located outside the pipe gallery underneath the filters. They are direct connected to the clearwater reservoir.



The Pumping Station

Westinghouse Turbines Driving Worthington High-Lift Pumps and Generators Supplying Power to the Raw Water Pumps 3 Miles Distant. Total High-Lift Pump Capacity Is 12 M.G.D. from a Clear Well of 2,000,000 Gals. Capacity.



The Boiler Room

Two B. & W. Stirling Boilers of 252 H.P. Each, Equipped with Forced Draft and B. & W. Chain-Gate Stokers. Average Evaporation 8.05 Pounds of Water per Pound of Coal Burned.

The filtering media consists of 25 inches of filter sand having a specified effective size of between .35 and .45 m.m. and a uniformity coefficient of not greater than 1.7. This sand overlies 5 inches of torpedo sand having an effective size of from .8 to 1.2 m.m. and a uniformity coefficient of not over 1.7 which in turn is on top of a 24-inch gravel bed. The gravel bed is deposited in 5 layers as follows:

Bottom	6 inches around lateral pipes	2½-inch to 1½-inch
Next	5 inches around lateral pipes	1½-inch to ¾-inch
Next	5 inches around lateral pipes	¾-inch to ½-inch
Next	4 inches around lateral pipes	½-inch to ¼-inch
Top	4 inches around lateral pipes	¼-inch to 1/12-inch

The filter operating gallery is very commodious. The arrangement of piping, controllers, etc., is such that there is freedom of access and adequate room for the removal of pipe or fittings or any service or repair work that may be necessary. (See cut.)

2,000,000 Gallon Clear Well

The two effluent conduits lead to a 2,000,000 gallon reinforced concrete clear well located in front of the main pumping station and filtration plant. This reservoir is 90 feet by 201 feet with a water depth of 15 feet. It is entirely covered over with lawn and the only evidence above ground of its existence are the ventilating manholes.

Much of the excavation for the filter plant and the clear well was in solid rock which accounts for certain features of the layout and the elevations.

Wash water is provided from a storage tank built underground on the side hill approximately 250 feet distant from the filter plant. This concrete tank stores 95,000 gallons. Its bottom is located 34½ feet above the sand. The wash water tank is connected to the pipe gallery through a 24-inch cast iron pipe. Filters are normally washed at a 24-inch rise but piping and troughs are designed for 36-inch rise. Filters are washed when the loss of head reaches 8 feet, or at 80 hours. Much of the time due to the low turbidity of the settled water the filters show but 5 feet loss of head when washed at 80 hours. Wash water averages 1½ per cent.

Surface Wash Under Trial

Filter sand is expanded 50 per cent during washing. Some mud balls are experienced. One filter has recently been equipped with surface wash. Its use has reduced the amount of mud balls 35 per cent in two weeks.

Operating Data

Chlorine in the average amount of 8⅓ pounds per M.G. is applied to the raw water at the McDaniel Lake pumping station. This is sufficient to obtain a residual of .4 to .8 p.p.m. after 30 minutes contact. Mr. Piner, the bacteriologist, advises that this prechlorination is largely responsible for the reduction in non-confirming lactose fermenters which were found in only .7 of 1 per cent of the tubes in 1940. Of the 5475 10-ml. lactose tubes inoculated with plant water only 39 showed the presence of any lactose fermenting organisms and none of these proved to be of coliform types.

Chlorine is again applied at the mixing chamber in amount sufficient to carry through the entire treatment process and show a residual in the effluent. Residual of .3 p.p.m. is carried as water leaves the plant, post chlorination being used when necessary.

Ammonia at the rate of 2 pounds per M.G. is applied as the water enters the clear well.

Average quantities of other chemicals used in 1940 were:

Alum	78.1	lbs. per M.G.
*Lime	43.1	lbs. per M.G.
Carbon	10.95	lbs. per M.G.

*To maintain P.H. of 7.3

Architectural Treatment

The new plant is located in a naturally beautiful wooded setting with rough topography typical of the Ozarks. In the development of the layout and design every effort was made to harmonize the construction so as to most effectively fit in with the topographical and physical features of the site. The grounds are a well kept natural park, provided with facilities for outdoor cooking, picnics, etc., and are considerably used by the citizens of Springfield for recreational purposes. Such use of the grounds has done much to improve public relations.

The colonial type of architecture selected for the exterior (see cover picture) was nicely adapted to the engineering requirements of space and arrangement. The head and chemical house at the center location separates the filters from the steam plant. The building is fireproof throughout. Interior walls are faced with a buff tile pleasing in texture and appearance; all floors are of quarry tile of variegated colors, harmonizing with the other interior construction. Chemical feed room is separated from the main hall by full glass partition walls.

One feature of the operating gallery of the filters is worth notice, namely, the curved roof design of the self-supporting type with no visible steel trusses or their equivalent.

The principal items of construction and their approximate cost are as follows:

Boiler House and Pumping Station	$186,737
Boiler Plant Equipment	89,167
Pumping Station Equipment	153,950
Outside Piping	28,698
Settling Basin	81,690
Filters and Head House	242,000
Clear Well	70,885
	$853,127

Contractors and Sub-Contractors

The following manufacturers furnished equipment for the new work:

Equipment	By Whom Supplied
Boilers (Stirling Type, 283 H.P.)	Babcock & Wilcox
Boiler Feed Regulators	Copes
Boiler Feed Pumps (Marine Type)	Worthington
Coal Elevator	Link-Belt Co.
Chlorinators	Wallace & Tiernan Co.
Dry Feeders	Wallace & Tiernan Co.
Filter Operating Tables	Norwood Engineering Co.
Filter Controllers and Gauges	Builders Iron Foundry
Flocculators	The Dorr Co.
Generators	Westinghouse
Make-Up Water Evaporator	Griscom & Russell
Metering Equipment	Builders Iron Foundry
Pumps	Worthington
Soot Blowers	Diamond
Stokers (Chain Grate)	Babcock & Wilcox
Superheaters	Babcock & Wilcox
Turbines (Steam)	Westinghouse
Valves (Hydraulic)	Ludlow Valve Co.

The Springfield City Water Co. is owned and operated by the Consumers Water Co. of Portland, Maine, of which Vernon F. West is President. Jasper Everett is Resident Manager of the Springfield property, and Raymond E. Piner is plant chemist and bacteriologist.

The Burnip Construction Co. of Columbus, Ohio, was general contractor on the execution of the entire work. The engineering design was under the general direction of Alvord, Burdick & Howson of Chicago, who also had detailed responsibility on all items of the filtration plant. Herman Burgi of Portland, Maine, collaborated on the details of the boiler and pumping equipment and John P. Thomas of Portland, Maine, was Architect.

WATER AND SEWAGE PATENTS

Reported by JULIAN F. SMITH
ASSOCIATE DIRECTOR
Hooker Scientific Library, Center College
FAYETTE, MO.

This page constitutes a new service to readers of WATER WORKS AND SEWERAGE, *many of which are interested in patents issued that pertain to some phase of water supply, water treatment, sewage disposal, and waste treatment.*

It is proposed to print these patent abstracts from time to time, as the number becoming available justifies. This service began with our March issue.

Water Patents

Boiler Feed Water. E. F. Walsh (to Narragansett Electric Co.). U. S. 2,234,786, March 11. In softening water by precipitation of a complex calcium orthophosphate the reaction is catalyzed by adding with the phosphate reagent a small proportion (not over 5 p.p.m.) of a soluble iron compound.

Water Pump. Greek S. Shupe. U. S. 2,235,174, March 18. A pump line in which the cylinder has an internal shoulder above it, and a latch removably engaging with the shoulder.

Sedimentation. Wm. B. Marshall (to Chain Belt Co.). U. S. 2,235,459, March 18. Water containing both inorganic and organic solids in suspension is passed through a settling basin at a rate which permits inorganic solids to settle but no organic solids, and is recycled to remove any organic solids which may have settled during periods of subnormal flow velocity.

Cation Exchange. T. L. Wilson (to U. S. Rubber Co.). U. S. 2,235,971, March 25. A new insoluble synthetic resin, derived from ethylene dichloride, and an aromatic hydrocarbon, having cation exchange properties.

Pipe Locating and Protecting Device. John F. Mahlstedt. U. S. 2,236,295, March 25. Laying a wood board over the outlet and pipe where buried pipes have underground upwardly projecting outlets.

Sedimentation Apparatus. John H. Knowles. U. S. 2,236,434, March 25. A sedimentation tank having a tubular drum with an annular seal at its bottom, and blades carried by arms extending from the drum for agitating the settled layer.

Water Well Cap. H. R. Mark (to Clayton Mark & Co.). U. S. 2,237,680, April 8. A sealing cap for a water well casing has upper and lower split disks having a divided resilient packer between them, the upper disk having a peripheral shoulder to rest on the casing, means being provided for sealing the drop pipe and casing with the resilient packing.

Water Purification. J. H. Morgan (to Crane Co. of Minnesota). U. S. 2,237,711, April 8. Freeing water from iron by passage through an aerating chamber and then through a gravity filter.

Iron Removal. J. P. Lawlor and V. M. Roach (to General Filter Co.). U. S. 2,237,882, April 8. Passing water under pressure into a pressure tank while passing fine bubbles of air into the water, and filtering the water in the pressure tank.

Removing Iron from Water. Jos. P. Lawlor. U. S. 2,239,612, April 22. An iron removal system having a raw water storage tank with a compressed air space above the water level; a repression tank also having a compressed air space above the water level; a filter between the storage and repression tanks; and a back-wash line connected to the feed pipe from the raw water storage tank to the filter.

Reagent Proportioner. George Ornstein. U. S. 2,238,747, April 15. Apparatus for feeding a controlled proportion of a fluid reagent to a flowing stream of another fluid, with the aid of a flow-responsive device and a casing in which the

flowing stream acts as a pressure medium.

Clarifying Water. J. W. H. Uytenbogaart (to Shell Development Co.). U. S. 2,236,930, April 1. Use of a dialkylcetylsulphonium salt as a clarifying agent for turbid waters.

Venturi Tube. J. M. Montgomery and Eric Pick (to Permutit Co.). U. S. 2,240,119, April 29. An adjustable Venturi tube has a converging inlet section, a throat, a diverging outlet section and an axially movable torpedo-shaped needle arranged so that movement of the needle is a linear function of the rate of flow.

Hydraulic Machines. Eric Pick (to Permutit Co.). U. S. 2,240,163, April 29. An improved mechanism, with stacked valve units, for controlling fluid flow in hydraulic or pneumatic machines.

Proportioning Chemicals. Eric Pick (to Permutit Co.). U. S. 2,240,-163, April 29. Apparatus for proportioning the feed of chemicals to a water under treatment.

Water Softener. N. E. Brice and C. M. Guldner (to Permutit Co.). U. S. 2,240,171, April 29. Means for automatic backwash variation in an electrically operated automatically controlled regenerative base exchange water softener.

Sludge Removal. C. M. Guldner and Eric Pick (to Permutit Co.). U. S. 2,240,182, April 29. Improved apparatus for automatically desludging a settling tank at fixed intervals.

Corrosion Prevention. Wm. E. Caldwell. U. S. 2,240,206, April 29. Supplying feedwater to a boiled from an economizer which is adapted to mix the feedwater with water drawn from the boiler.

Sterilizing Unit for Filters. H. B. Hartman (to Norwood Filtration Co.). U. S. 2,240,648, May 6. A sterilizing unit to be interposed in a water pipe in connection with a water filter.

Water Tester. L. G. Daniels (to Elgin Softener Corp.). U. S. 2,241,-121, May 6. An automatic hardness tester with means for feeding a measured sample and a known quantity of soap solution into a test chamber.

Clarifying Water. R. R. Magill (to J. F. and G. K. Gunther). U. S. 2,241,641, May 13. Clarifying turbid water with sodium chloride, sodium aluminate and waterglass.

Water Softener. Eric Pick (to Permutit Co.). U. S. 2,241,887, May 13. A regenerative water softener to be used in connection with automatic washing machines.

Filtration Tank. Chas Lose, Jr. U. S. 2,242,082, May 13. An oval filter tank containing a filter bed and a cleaner operating on rails above the filter bed.

Water Purification. Walter C. Munroe. U. S. 2,242,139, May 13. Floating a flocculent precipitate in quiescent water by aerating with fine air bubbles.

Settling Tank. Benj. F. Soffe. U. S. 2,243,582, May 27. A settling tank with co-axial vertically spaced uptake funnels for withdrawing clear liquid.

Water Softener. D. G. Griswold (to Clayton Mfg. Co.). U. S. 2,243,-815, May 27. Water softening apparatus having a softener tank, a brine tank and means for feeding water to the softening tank at one end for softening, and at the other end for back-washing.

Sewage Patents

Sludge Removal. Sydney B. Poole. U. S. 2,236,128, March 25. A sewage tank is fitted with a traveling gantry for removal of settled sludge by sweeping the bottom of the tank with water jets.

Scum Remover. R. E. Briggs (to Jeffrey Mfg. Co.). U. S. 2,237,172, April 1. Fitting a sewage settling tank with a scum trough extending across one end, and a ramp along which the trough is moved by a chain flight conveyor.

Distillery Wastes. A. W. Lissauer (to Louisville Drying Machinery Co.). U. S. 2,236,800, April 1. Filtering thick distillery slop and clarifying the cloudy filtrate with a precipitating agent to form a clarified liquid with lowered biological oxygen demand.

Municipal and Industrial Wastes. John Mohr and Ernest Lagelbauer. U. S. 2,238,367, April 15. Carbonizing municipal and industrial wastes by heating with insufficient air for combustion, and hydrogenating the volatile products to form useful substances, including liquid hydrocarbons, ammonia, fuel gas, acetic acid and alcohols.

Fiber Recovery. Adolf M. R. Karlström. U. S. 2,240,403, April 29. Recovering paper fiber from white water in paper mills by adding an aluminum compound and a sulphonated oil.

Sewage Treatment. F. R. Maxwell (to Sun Shipbuilding & Dry Dock Co.). U. S. 2,242,652, May 20. Agitating raw sewage to agglomerate the solids, filtering and returning a portion of the filtrate to wash back the filter bed.

Treating Sewage. A. F. Nielsen and W. L. Paulison, Jr. (Paulison assignor to Bailey Meter Co.). U. S. 2,243,826, May 27. Introducing a treating chemical into sewage or industrial wastes in proportioned flow, modified by an established time cycle.

A RECORD HAUL

Not long ago our eyes fell on an interesting editorial in the N. Y. Evening Sun which commented on notably bold thefts, involving such things as entire railroad tracks, a contractor's locomotive, and the like.

The editorial ended by commenting that the real record for such heavy loot crimes was apparently established in Groveton, Texas, when two men stole the entire water works of the town, and *while it was in full operation*, to boot.

A WORD OF WARNING, PERHAPS

Suspect Found With Maps of N. Y. City Water System

Newspaper accounts have it that a man seized as a suspect in connection with the clean-up of the German-American Bund was found to have in his possession maps of the New York City water supply system, which he could not explain to the satisfaction of FBI agents. He also had a diary or notebook written in code.

We are printing this report for what it may be worth, since we have had no opportunity to obtain confirmatory information or more exact facts concerning the case. We have an idea, however, that the Nazis are not lacking in regards information of this same nature in connection with other important water supply systems.

THE MAINTENANCE OF LARGE METERS IN THE FIELD

By D. R. TAYLOR, Plant Superintendent
ROANOKE, VIRGINIA

The Author

WHILE most of the preachments on meter maintenance have laid stress principally on domestic meters, the maintenance of larger commercial and industrial meters is of equal importance. Although large meters may account for only a minor portion of your total revenue, underregistration of these meters to any great extent may constitute a major part in your sufficiency of reserve supply, and the accounting for of your input into the distribution system.

A large industrial consumer may be furnishing only two per cent of your total revenue, yet using ten per cent of your total consumption through a meter that is forty per cent slow in registration. Besides the monetary loss in such a case, the daily quantity not registered may amount to several per cent of your total input or several hundred thousand gallons per day. We have seen such an existing condition blandly ignored, or at least passively tolerated, by those who would break a hamstring to get a gang out to stop a small service leak at night rather than let it run harmlessly until morning. The average water works superintendent will expend any amount of effort and money necessary to stop a leak in his distribution system; yet, many of them display a surprising degree of apathy towards checking the registration of large meters where a correction may pay even greater dividends than in stopping a main leak. We, at Roanoke, have followed a carefully supervised meter maintenance program for almost ten years, and our records show that we are receiving dividends in the form of increased revenues as a result of such a program amounting to several times our annual cost of such maintenance.

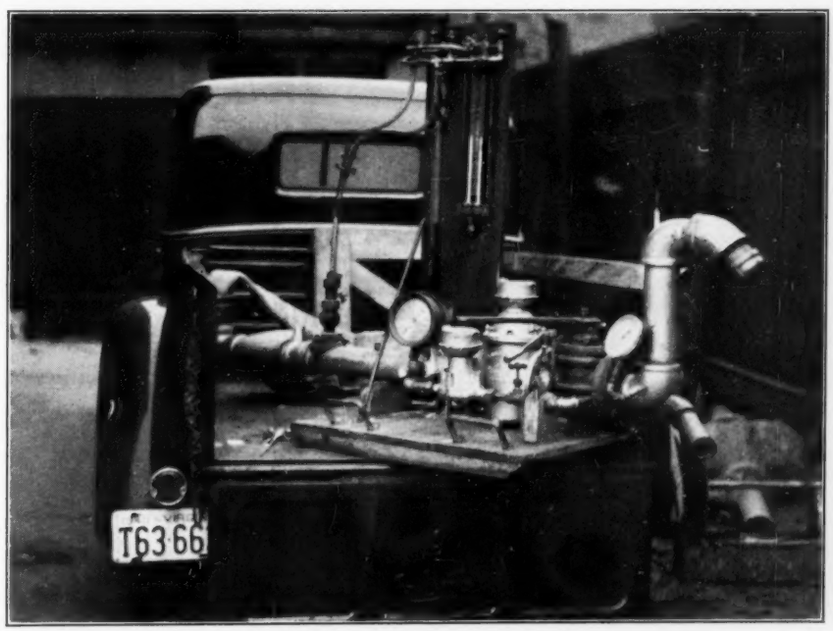
Some capital expenditures are of course necessary at the beginning of such a maintenance program for the installation of test tees and by-passes if these were not included in the original installation. It will also be necessary to provide a test meter, which can be purchased complete or assembled at your shop. Ours, shown in an accompanying photograph, con-

Chart I

TEST RATES—G. P. M.

(Standard for Roanoke Meter Tests)

Type	Size	Gallons per minute — Min.	1st	2nd	3rd	4th	5th
Disc	1½"	1	1.5	6	40	80	...
	2"	1	1.5	6	40	100	...
Compound .	1½"	.25	1	5	40	80	...
	2"	.25	1	5	40	80	100
	3"	.5	1	6	40	80	150
	4"	.5	1	6	40	80	200
	6"	.5	1	6	40	80	250
	8"	.5	1	6	40	80	300
Protectus ..	3"	1.5	2	6	40	100	200
	4"	1.5	2	6	40	125	200
	6"	1.5	2	6	40	125	250
	8"	1.5	2	6	40	125	300
Detector ...	3"	1.5	2	6	40	125	200
	4"	1.5	2	6	40	125	200
	6"	..	4	10	40	125	250
	8"	..	4	10	40	125	300
Current ...	1½"	5	..	10	40	80	...
	2"	7	..	10	40	80	150
	3"	10	..	20	40	100	200
	6"	15	..	20	40	100	250
	8"	30	..	..	40	100	300



Field-Test Meter and Accessories

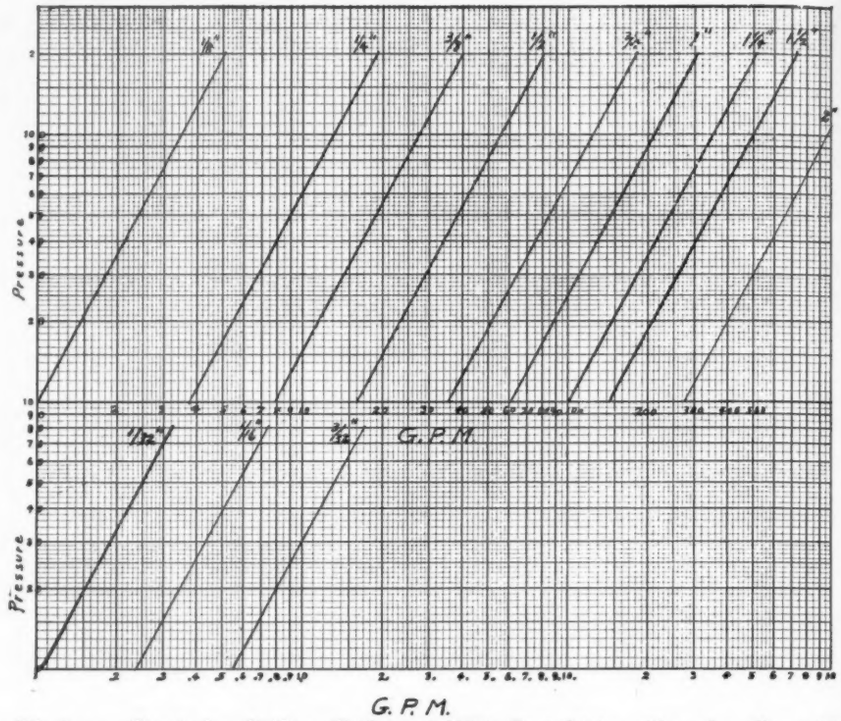
A 3-in current type and ⅝-in disc type meter, the case of the former being of silicon-aluminum to reduce weight. Note the pitot-rod and manometers for flow rate control.

sists of a three-inch current type meter and a ⅝-inch disc type meter with special test dials, proper valves, connections and accessories which will be explained later.

The case of the current type meter is of silicon-aluminum, to eliminate as much weight as possible, and was especially made for us by one of the leading meter manufacturers.

Experience in Method and Frequency of Test

The frequency of testing large meters depends upon the corrosiveness of the water measured and the monthly consumption through them. With one hundred and ninety large meters from one and one-half inches to eight inches in size, our experience shows that the economic frequency of test in our plant is once per year for all types except discs, and every three years for those. We also learned early that the old method of testing with various size orifices, without regard to actual rates of flow, was entirely inadequate and was apt to lead to false interpretations of the records. For instance, three different six-inch Protectus meters may be tested at three different locations with a one and one-fourth inch orifice. Differences in elevations may result in full flow pressures we will say of twelve, twenty-four, and thirty-six pounds per square inch respectively at the three locations. This means that one meter has been tested at a rate of 110 g. p. m. (below the change over point), one at 160 g. p. m. (exactly at the change over point), and one at 200 g. p. m. (above the change over point). It is obvious that, while these three meters were not only of the same size but also of the same manufacture and tested with the same size orifice, the three tests are not comparable. Hence the necessity for standard testing specifications and methods.



Discharge Graph for Orifices Calibrated With Test Meter. (See also Chart 3.)

Standard Test Rates Established

We devised standard test rates for all meters, as shown in chart one.

We next installed a 750-gallon steel tank on our pumping station grounds and calibrated it with a ten-gallon tested measuring can. This tank is buried in the side of a hill in such a position that the small truck carrying our test meter can be driven close and over it, so that the test meter can be easily and quickly tested volumetrically. After calibrating the test meter, we calibrated each of the orifices with the test meter. These results were first plotted on logarithmic graph paper as shown by Chart 2.

From Chart 2, we made up for use in the field Chart 3, which reveals the delivery of the several orifices at various pressures.

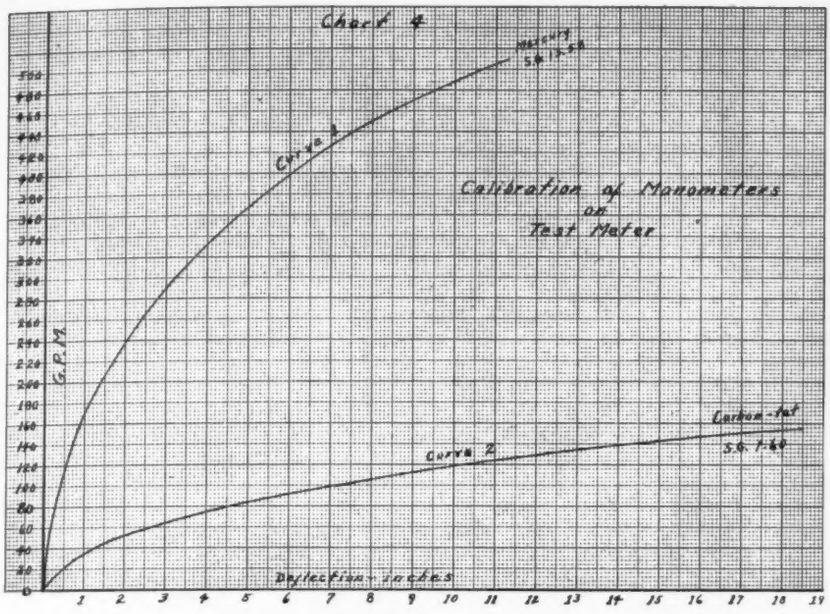
A Pitot Rate Indicator

We installed a pitot rod through a corporation stop in the three-inch inlet pipe of the test meter and ten-diameters ahead of it. (The make and coefficient of this pitot rod being unknown, it had been discarded; however, this knowledge is not necessary for its present use.) Two manometers were mounted on a board on the test meter base in such a position that the operator can observe them while he operates the discharge valve—see cut. These manometers can be inexpensively made with boiler gauge glass sets.

The two manometers are connected with rubber tubing and proper valves, so that either can be operated independently by the one pitot rod. One manometer contains carbon-tetrachloride, with a specific gravity of 1.60 for low rates of flow,

Chart III
FIELD CHART
(*Gallons per minute*)
Pressures

Orifice Size	.25	.5	1	1.5	2	4	5	6	7	10	15	20	30	40	80	100	125	150	200	250	300
1/32"	50	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1/16"	11	40	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3/32"	..	9	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
⅛"	..	..	10	21	36	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
¼"	..	..	..	..	..	11	17	24	32	60	..	..	..	..	..	..	..	..	..	..	..
⅜"	..	..	..	..	..	..	..	..	8	11	34	56	..	..	..	..	..	..	..	..	..
½"	..	..	..	..	..	..	..	..	..	..	9	10	32	55	..	..	..	..	..	..	..
¾"	..	..	..	..	..	..	..	..	..	..	..	..	7	13	46	..	..	..	..	..	..
1"	..	..	..	..	..	..	..	..	..	..	..	..	..	..	17	26	38	54	93	..	..
1¼"	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	15	21	36	54	77
1½"	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11	19	29	40
2"	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	12



Calibration Graph Made on Manometers
(From which the brass scales were prepared.)

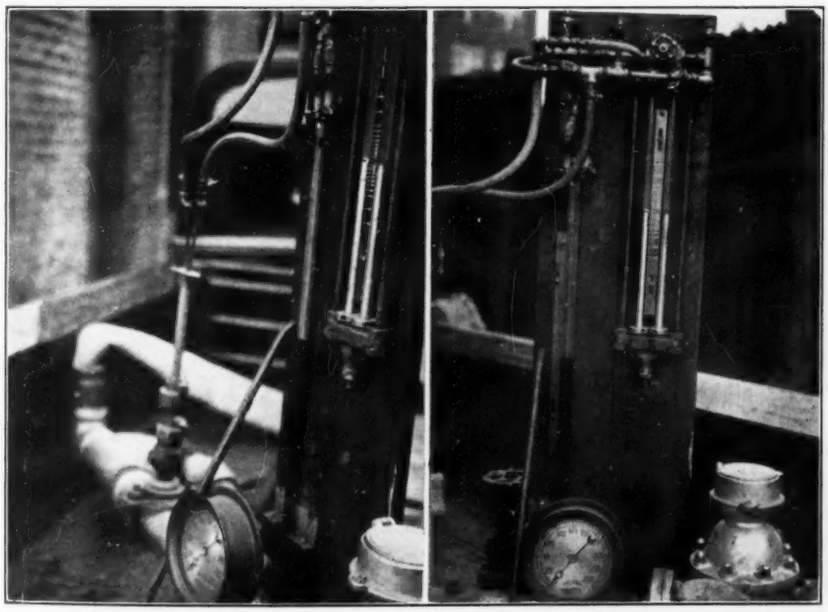
and the other contains mercury with a specific gravity of 13.58 for the higher rates of flow. The pitot rod and each of the manometers were then calibrated with the test meter, and the results plotted as shown on Chart 4.

From this chart, brass scales were made for each of the manometers by marking on narrow brass strips the rates in gallons per minute indicated by various deflections of the manometers. The operator therefore opens the discharge valve (a plug type has been found more satisfactory) until the deflection in the manometer indicates any desired rate as shown on the scale.

Rates from .25 g. p. m. to 6 g. p. m. through the five-eighths inch side of the test meter are too low for measurement by either manometer, yet are low enough to be easily obtained and controlled by a needle valve, orifices and a pressure gauge in accordance with Chart 3. Rates from 10 g. p. m. to 120 g. p. m. may be controlled by the carbon-tetrachloride manometer, and rates from 80 g. p. m. to 400 g. p. m. may be controlled by the mercury manometer. This outfit has performed very efficiently and economically for the last two years.

To those who are interested in constructing such an outfit and find it necessary to purchase all parts new, we would suggest that they also investigate the Henszey Flow Indicator. This instrument may be cheaper than a new Pitot rod and manometers and will probably give results equally as satisfactory.

The purpose of this discourse has been to show the fallacies in the use of the old methods and the advantages of other methods of testing large meters on standard rates according to size, so that the results are comparable and can be properly and advantageously interpreted and analyzed.



The Pitot Rate Indicator Attached to the Test Meter Unit
On left is seen the pitot rod and dual manometer for high and low pressure testing. On right is better shown the method of connecting the carbon-tetrachloride and mercury manometers, also the etched brass plate indicating in gals./min. direct.

FELIX SELIGMAN PASSES

Felix Seligman, manager of the Water and Light Dept. of Duluth, Minn., passed away on May 29th in his home, after an illness of several months.

Mr. Seligman had been employed in the Water and Light Dept. of Duluth since 1921—first as Supt. of Pumping Stations until 1934, when he was made manager of the Water and Light Dept.

Mr. Seligman was a member of the Board of Directors of A.W.W.A., representing the Minnesota Section at the time of his death. He was intensely interested in Boy Scout work and directing a troop for 16 years. He was also commanding officer, 50th Div. U.S.N.R.

ELIAS NOW DISTRICT ENGINEER, PA. DEPT. OF HEALTH

George A. Elias, formerly assistant engineer in the Philadelphia District Office of the Pennsylvania Department of Health, has been appointed by the Secretary of Health as district engineer in charge of that office. He succeeds former District Engineer Harry M. Freeburn, who resigned to accept the position of chief engineer of the Philadelphia Suburban Water Co.

SOUTHEASTERN SECTION MEETS IN HISTORIC CHARLESTON

In the Birthplace of Cement Lined C. I. Pipe the Fuller Award Was Voted James E. Gibson for This and Other Contributions

THE Southeastern Section of A.W.W.A., holding its 13th Annual Meeting May 12th-14th in the city famed for its history, romance and aristocracy of the old South, devoted the first day to technical and business sessions and the second and third days to inspection trips. The registered attendance was 186.

Chairmen

(Retiring)
Frank M. Chapman
Supt. of Water
Greenwood, S. C.

(Incoming)
Marion G. Stewart
Supt. of Water
Natchez, Miss.

The first inspection trip took members and guests on a 23 mile run up to the new Charleston intake on the Edisto River, from whence the water travels to the filtration plant and pumping station by gravity through a tunnel constructed for its entire length through a soft limestone rock formation (referred to locally as marl) without the need of lining—something novel in water supply conduit construction. Aside from bringing to Charleston a water of better quality, less expensive to treat and in abundant quantity for long into the future, the cost of this project is being completely financed through water sales to the tremendous plant of the West Va. Pulp and Paper Co. with which a long term supply contract was negotiated and guarantees set which made the project financially feasible. The Charleston story is an interesting one, in which a compact with industry has brought to the citizens a more adequate supply of higher quality, and at a reduced cost of production.

As guests of the Board of Water Commissioners of Charleston luncheon was served on the filter plant grounds beneath moss festooned water oaks, after which the filter plant and pumping station were inspected. The day ended with a trip through the humming mill of the West Virginia Pulp and Paper Company, which daily purchass 25,000,000 gallons or more of water (untreated) at the filter plant and pumps it over to the mill.

The third day was devoted to an inspection trip over the $40,000,000 Santee-Cooper Power Development, constructed by a State Authority on the Santee and Cooper Rivers to produce 700,000,000 K.W.H. per year. This project, financed through P.W.A., was described in the first technical session as later reported. It is said to involve the world's longest dam which will total about 8 miles of concrete and earth fill construction.

A Test of Pipe Linings

An interesting feature of the trip to the Edisto Intake was the display of test sections of cast-iron pipe which had been given various protective linings and in service for about 3 years, carrying the soft corrosive water of Charleston. The study was being made by the American Cast Iron Pipe Co. for the purpose of determining the relative merits of various cement-sand lining mixtures, thickness of linings and the effectiveness of bituminous impregnating compounds. Although

"Brass Hats"

Guy W. White, Plant Supt., Columbia, S. C.
(National Director)
B. P. Rice, Engr., R.F.C., Atlanta, Ga.
(Sec'y-Treasurer)
Max G. Howe, Supt. of Water, Union, S. C.
(Trustee)

there was a pronounced difference between the interior condition of the ordinary tar dipped pipes (controls) and the impregnated cement lined pipes, the major difference between the latter appeared to be only a matter of smoothness, and sustained "C" value after 3 years of service.

General Summerall Dinner Speaker

At the annual dinner, attended by 280, the speaker was General C. P. Summerall, President of "The Citadell," which has been dubbed the "West Point of the South" and located in Charleston.

The general who commanded the First Division in France during the last World War made an extremely interesting address in comparing the first and the present World Wars, with emphasis on their comparative importance to and probable effects on the people of this nation.

Programmers

F. K. Ellis, Supt. Public Wks., Sumter, S. C.
(learned that a "wild" water could be tamed)
John M. Perryman, R. D. Cole Co., Newman, Ga.)
(gave some worthwhile pointers on tank maintenance)
H. M. Matthews, Supt. of Water, Thomasville, Ga.
(coagulates lime-soda treated water with Fuller's earth alone)

Gibson Honored

It seemed very fitting that in his home town Jas. E. Gibson, Sup't and Engr. of Charleston's Water Works, should have been chosen as the recipient of the George W. Fuller Memorial Award for his several contributions to better water supply practices.

The following citation drawn up by Paul Weir, Chairman of the Award Committee, was read by President Norman Howard.

"For conspicuous leadership in administrative, engineering and operating affairs of water systems, for meritorious research work and development of cement-lined pipe, all welded steel elevated water tanks and gravity unlined tunnel constructed in marl soil below sea level serving the city of Charleston, S. C., and environs, and for his long and effective years of service to the section and American Water Works Association, of which he is Past President."

(As we write this we can think of other honors to Mr. Gibson by A.W.W.A., which probably makes him the most honored member of

On the Charleston Inspection Trip

(1) Asst. Manager and Engr. McDowell (with pipe) explaining the construction of Charleston's unique water tunnel—see text. (2) Left to right—F. M. Hunt, Supt. Water, Light and Sewers, Seneca, S. C.; Chas. Floyd of Badger Meter Co., Lewis Davis of Hercules Powder Co., Atlanta, and J. M. George, Supt. of Water and Sewerage, Thomaston, Ga. (3) In this picture somebody is asking a lot of questions about this particular length of pipe in the lining service test—the questioner is F. M. Hull of Columbus, Ga. (4) A couple of "ACIPCO" smiles over the outcome of the linings demonstration—(left) Tom Starnes, Southern Labs mgr., and (right) R. R. Deas, Jr., Acipco's asst. works mgr., Birmingham. (5) Chas. H. Starling, International Filter Co., Charlotte, N. C., and R. W. Ockerhausen, General Chemical Co., New York.

the Association. In 1929 he received the John M. Diven Medal. In 1940 was conferred upon him Honorary Membership. As announced in our May issue, and before this number reaches readers, Mr. Gibson will have received the honorary degree of Doctor of Science from the University of Arkansas—his Alma Mater. —L. H. E.)

Officers

Chairman

M. G. Stewart, Sup't of Water, Natchez, Miss.

Vice-Chairman

Frank G. Crow, Manager, Water Department, Florence, S. C.

Secy.-Treas.

B. P. Rice, Engr., R.F.C., Atlanta, Ga.

Trustees

J. T. Pinkston, Sup't, Meridian, Miss.; W. W. Pointer, Sup't, Troy, Ala.; M. G. Howe, Supt., Union, S. C.; G. H. Sparks, Sup't, East Point, Ga.

National Director

Guy H. White, Sup't of Filtration, Columbia, S. C.

Technical Sessions

(Chairman F. W. Chapman Presiding)

The first paper of the one day technical sessions was that describing some of the more interesting features of the Santee-Cooper Dam and reservoir construction in the power and navigation project being put through near Charleston, S. C., at a cost of $40,000,000, for which a 45 per cent grant was secured from P.W.A. This project is to be completed by October, 1941, and turned over to the State Public Service Authority to operate.

The description of the dam and reservoir was presented by *L. F. Harza,* President, The Harza Engineering Company, employed as Supervising Engineers on this project, which includes the world's longest dam (8 miles), involving 20 million cubic yards of earth dam and a main dam of hollow concrete buttress design. The initial power developing capacity will be 173,000 H.P. with ultimate installation of 213,000 H.P. Operating head is 70 feet on the turbines, and 60 feet as the lowest anticipated head under severe drought conditions.

Hosts

S. S. Booker, Chm'n of the Water Board Jos. E. Gibson, Gen'l Mgr. and Engineer F. B. McDowell, Asst. Mgr. and Engineer

With great width of reservoir (10 miles across at points) soil protection was a problem of moment. To combat wave action a porous concrete slab, laid on a gravel blanket foundation on slopes, is new. The porous concrete slab is constructed of gravel of ¼ inch to ¾ inch size and cement (without sand) in ratio of 0.94 bbl. of cement to the cubic yard of mix. That the consistency of mix (water ratio) is judged by observing power imput required to rotate the mixers, was also an interesting disclosure. Mr. Harza explained that dense concrete slabs were frequently destroyed by wave action heaving the slab from beneath, wheras porous concrete did not suffer from up-lift pressure and, further, that frost action was not destructive of porous concrete.

Elevated Tank and Standpipe Maintenance

On this topic two papers were presented. The first was by *H. F. Stearns,* of the Chicago Bridge and Iron Co., Birmingham, Ala.

Mr. Stearns suggested to water operators that for the same reason they keep their homes well painted they should keep tanks well painted. If one was a good investment so was the other, but that idea wasn't always easy to "sell" and therefore there are still two groups—the maintainers and the non-maintainers.

Concerning frequency and methods and materials to employ in protection of tanks and standpipes, Mr. Stearns said that preparation of the metal in applying the shop coat had much to do with paint longevity. In pickling steel sheets for tanks phosphoric acid seemed best and most economical in the long run. The prime paint coat should be applied while the metal is still warm.

For interior protection, of all the coatings listed bituminous coating applied hot seemed the most permanently effective and in the long run likely the most economical. Mr. Stearns briefly described cathodic protection, of which there are more than 200 installations, most of which had been considered to be doing a satisfactory job. However, the portion of the tank above flow line and the underside of the roof deserved attention when the cathodic process is employed.

(1) Luncheon at the filtration plant under moss festooned live oaks. (2) Inspecting many lengths of pipe after 3 years of lining service test. (3) John Benke, for 21 years supt. of maintenance at Charleston; Richard Ford, Ford Meter Box Co., and D. W. Thorp, mgr. Hamlet Water Co., Hamlet, N. C. (4) At Edisto intake, where Charleston's water enters the 23-mile-long tunnel to the filtration plant. (5) Genl. Mgr. Gibson and group at Edisto intake.

(1) *Activated Alum Corp'n out in force; Bert Graham, manager of the new Charlotte office; Howard Stilwell, specializing on the Tate pipelining process, and Merbe Shoemaker, also from Activated's Baltimore office.* (3) *Rossiter Scott, engineer, Dresser Mfg. Co., and S. S. Booker, Charleston's water board chairman.* (4) *A golfing threesome, Henry A. Perkerson, M. & H. Valve & Fittings Co., Anniston, Ala.; Benn F. Crabbe, McWane C. I. Pipe Co., Birmingham, and Z. A. Stanfield, Pittsburgh Meter Co., Memphis, Tenn.* (5) *John Hawkins, supt., Greenville, S. C.; F. K. Ellis, supt., Sumter, S. C., and D. W. Johnson, research engr., Cast Iron Pipe Research Ass'n, Chicago.* (6) *John T. Woodson, asst. sales mgr., Nat'l C. I. Pipe Co., spins a yarn about World War No. 1 to Lt. Col. Coyle, U. S. Marine Corps. The Navy man is Commander Angas of the Charleston Navy Yard, which depends upon the city for its water needs.*

John Perryman, Sales Engineer, R. D. Cole Co., Newnan, Ga., had so much to say concerning tank maintenance that this space is to be too inadequate to do his contribution justice.

His first recommendation was to employ a competent man to make an inspection of the tank every 4 to 5 years—a man who would "look behind the ears" of the tank, so to speak. In outlining what an adequate inspection entailed, Mr. Cole stressed the need for looking at the underside of struts, rods, bolts, ladder rungs, etc., where corrosion always begins and is most progressive. In many sections the first part of the tank shell to go is the area above the water line and the roof—watch these. Concerning rivets, he pointed out that their strength was in the shank—not in the heads. Therefore, pitting of rivet heads may mean very little other than bad looks. Hammering is bad business because it jars the shank loose and leaks develop where otherwise not. Foundation piers are usually neglected; and should be protected with a bituminous seal coat to keep out the water.

Concerning cleansing of the walls, preparatory to painting, Mr. Perryman said wire brushing was ample. Sand blasting is costly, disagreeable and lacking in merits. For painting interiors he advocated 2 coats of red-lead (or the newer inhibitive lead-chromate) plus a finish (3rd) coat of black bituminous paint. To the red lead, 10 per cent litharge added would hasten hardening. For the outside finish be advocated the use of aluminum powder in the Navy specification synthetic vehicle, known as U. S. Navy Vehicle D-10-2.

In the cost of painting, the total will divide about half for paint and half for labor. In any case it would pay to employ the most reliable and experienced contractor who can be depended upon to employ the best of materials and workmen.

In reply to questions from the floor, Mr. Perryman said (1) that for the roof and upper shell he would recommend the Navy formula synthetic resin vehicle D-10-2; (2) a single coat of aluminum paint over red-lead would not be sufficient, since the red would streak through the aluminum.

John Hawkins, Supt. of Water, Greenville, S. C.

George H. Sparks, Supt. of Water, East Point, Ga.

F. B. McDowell, Asst. Mgr., Charleston, S. C.

Mr. Harza revealed that on the flood gates of the Cooper-Santee Dam they were applying a sprayed on coating of pure molten zinc—the method being known as "metallizing."

At this point interest swung to cathodic protection. One user, Mr. L. V. Gaffney, Sup't at Gaffney, S. C., said that so far his observations were that it was doing a job. Mr. E. H. Ingle, President, Electro Rustproofing Co. of Dayton, Ohio, was then asked to explain the cathodic scheme, which he did. Reporting now 500 installations, and still increasing in rate each month, Mr. Ingle stressed the fact that each installation must be engineered individually on the basis of such factors as water quality, diameter of tank, temperature range, etc. Concerning protection of wall area above mean water levels, Mr. Ingle stated that so long as the level reaches maximum once during each day protection would be had; otherwise, this strip should be kept painted. In addition to the tank walls, the tank riser was also protected cathodically but the effect is somewhat slower.

In reply to questions he stated that (1) Current costs of $25.00 yearly had been maximum for 500,000 gal, tanks. (2) The method could be applied to old tanks, but if the rust was all that was stopping leaks cathodic protection could not prevent leaks when the rust dropped away, as it always did. (3) Paint patches in good condition would remain in place during cathodic protection, if rust had gotten behind the paint it would slough off along with the rust. (4) Old scale and rust need not be removed when starting cathodic protection.

Reverting at this point to protective coatings, the question was raised concerning iron oxide itself as a protective coating. Since it was nature's own coating for iron and steel why should it not be employed as a protective pigment. Mr. Perryman replied that some of the older heads in his company were strong for the oxide paints.

Then the discussion swung to "No-Oxid," which has as a base a stiff non-emulsifying grease that is applied over rusted surfaces cleaned only of the loosely adhering scale. C. L. Armstrong of the Dearborn Chemical Company in explaining the

(1) *From Natchez, Miss., H. S. McElroy, commissioner, and M. G. Stewart, supt. of water (the new chairman of the section).* (2) *Wm. J. (Bill) Lyman, southern sales mgr., Nat'l Cast Iron Pipe Co.; Birmingham, and Tom J. Boyd, Moreland Chemical Co., Spartanburg, S. C.* (3) *From Newman, Ga., R. C. Atkinson, secy., and H. H. North, chairman of the Water and Light Commission.* (4) *J. L. Hodgson, Atlanta representative, and A. Clinton Inglee, president, Natl. Water Main Cleaning Co., New York.* (5) *J. J. Murray, president, Murray Laboratories, Greenville, S. C., and W. M. Rapp, Atlanta manager, Mueller Brass Co. of Port Huron, Mich.*

(1) *Ed. Hendricks, supt. of water and light, Cairo, Ga., and Ed Johnston, Nat'l Meter Div., Pittsburgh Meter Co., Palatka, Fla.* (2) *B. W. Crutchfield, chief chemist, Am. Enka Corp., Enka, N. C., and Guy H. White, plant supt., Columbia, S. C.* (3) *H. F. Wiedeman of Wiedeman & Singleton, engrs., Atlanta, and J. W. Lovejoy, supt. of water and light, Laurens, S. C. (past chairmen of the section, both).* (4) *Tom Tarver, plant engineer, and Harry Sudlow, supt. of water, Aiken, S. C. (34 and 37 years of service respectively).* (5) *M. K. Sanders (Atlanta) and F. A. Eidsness (Jacksonville) representatives of Mathieson Alkali Wks.*

applicatoin of "No-Oxid" said that it could be sprayed on or hand brushed and smoothed with a cloth covered wood block. The thickness of application recommended is 1/32 inch. He said that this coating is used by the U. S. Government for the inside of brine tanks and is satisfactory for water supply tanks also, being approved by several State Health Departments.

Treatment of Well Waters

Under this topic three papers were scheduled.

"Experiences at Thomasville, Ga.," by H. M. Mathews, Supt. of Water and Light, Thomasville, Ga.

Mr. Mathews briefly described the 1.5 m,g.d. softening plant of Thomasville, treating well water of 192 parts hardness by the lime-soda process, involving excess lime (40 p.p.m. caustic) in split treatment to drop out magnesium, and soda ash for calcium sulphate reduction. A finished water was produced averaging 73 p.p.m. soap hardness and 28 parts alkalinity, with a pH of 8.5 after primary and secondary recarbonation ahead of filtration. Secondary recarbonation to 22 parts of normal and 6 parts bicarbonates, on the average, produces a non-scaling water in hot water lines.

An interesting disclosure was the review of his experiences with coagulants. Neither filter alum or sodium aluminate had proved as efficient coagulants as Fullers earth. The economical dosage of 9 p.p.m. yielded filter runs of 70 to 80 hours, as against 30 to 40 hours for the aluminum coagulants. Prechlorination with sulphate of ammonia is employed.

Regarding chemical and power costs, and chemical dosages, the following is typical:

Chemical	Dosage	Cost/1,000 Gals.
Lime (hydrate)	214 p.p.m.	$1.06
Soda ash	17 p.p.m.	0.19
Fullers earth	9 p.p.m.	0.08
Total chemical		$1.33
Power		0.21
Water		0.19
Labor		0.91
Total operating cost		$2.64

"The Situation at Natchez, Miss.," by M. G. Stewart, Supt. of Water, Natchez, Miss.

The new chairman of the section related how "Old Man River" had cut in on well locations at the foot of the 150 foot bluff at Natchez until only 20 feet of the original plant site remained. In consequence a new plant had been located on top of the bluff and four 750 foot wells put down, giving ample yield but requiring iron and manganese removal and softening.

The raw water containing 8 parts free CO_2 is aerated by diffused air for 10 minutes. Lime is added to 20 parts causticity and ferrous sulphate serves as the coagulant, aided by 1.2 p.p.m. iron and 0.3 p.p.m. manganese in the water. The water is recarbonated with CO_2 diffused through "Alexoite" tubes, also employed in the aeration step.

The initial hardness of 263 p.p.m. is reduced to 69 p.p.m. and iron and mangansese completely removed.

Dr. Frank E. Hale, Director of Laboratories, N. Y. City Dept. of Water Supply
H. F. Wiedeman, Consulting Engineer, Wiedeman & Singleton, Atlanta
Paul Weir, Supt. of Purification, Atlanta, Ga.
(chairman of A.W.W.A.'s Purification Div., who this year was voted the Goodell Prize)

"Calgon for Corrosion Control at Sumter, S. C.," by F. K. Ellis, Supt. of Public Works Dept., Sumter, S. C.

Mr. Ellis said that for a long time he had not realized that the "wild water" of Sumter could be tamed. Sumter has two wells—one tame; one "wild." The wild one runs high in iron, gives red water aplenty. In consequence the troublesome well is used only to make up deficiency of supply—and consumers came to understand that during those times red water was a necessary evil, but now they had learned better. The story is that caustic-soda is now fed to supplement aeration in removing free carbon-dioxide and an experiment in "Calgonizing" this "wild water" had been a success in preventing the iron precipitation in the mains and correcting the red water troubles so long though inescapable.

Mr. Ellis explained that his experiment merely consisted first of hanging a burlap bag with Calgon in it in the stream from the trouble making well. The experiment was a success from the beginning. What dosage was used nobody would ever know. Then he got more scientific and had gradually reduced the Calgon feed (solution) to 4 p.p.m. to the iron well output, which meant 2 p.p.m. to the combined waters of both wells. So satisfied was he with this "miracle" he decided to cut out the caustic soda feed, but found that he had to return to it. In any event the combination of Calgon and caustic had made life much easier for a water works superintendent who had learned that "wild water" could be tamed after all.

General Discussion on Well Waters

It was pointed out that screens of copper wire over ventilators of a covered reservoir, receiving well water high in sulphide, had to be renewed very frequently. The question was what was a good substitute for copper? The best answer seemed to be to avoid all metals and use the coarsest cotton duck or burlap.

W. L. Averett, Ass't Engr., Georgia State Dep't of Health, reported that calcite contact filters had been very successfully used in "taming wild waters" in Georgia. To reduce the pick up of hardness through such units by solution of the limestone, alkali had been added to the influent water to cut down the free carbon dioxide.

Sup't George Sparks told of experiences in using dry-ice to force water back through the well bottom and raise the yield—also of the use of inhibited acid and "churning" with compressed air. The first scheme involved dropping 100 lbs. of dry ice into the casing and screwing on a cap. Overnight a 55-lb. pressure was built up. The acid-air scheme consisted of adding the acid and putting 70 lbs. air pressure on the capped casing, releasing the air

(1) *W. D. (Shorty) Taulman, president, W. D. Taulman & Associates, Atlanta, Ga.* (2) *Prof. H. A. Wycoff, Dept. of Civil and Hydraulic Engineering, Georgia Tech, Atlanta.* (3) *J. D. Leslie, supt. of water, Rock Hill, S. C.* (4) *L. V. Gaffney, supt. of water and sewerage, Gaffney, S. C.* (5) *W. L. Averett, asst. engr., Georgia State Dept. of Health, Atlanta.* (6) *Ralph R. Silver, Silver & Douce, Inc., Birmingham (long business manager of the Southeastern Section's Journal).* (7) *Carl C. Lanford, supt. of water, Newton, N. C.* (8) *Chas. Floyd, Jr., representing Badger Meter Co., Greenville, S. C.*

and repeating the churning operation.

Linn H. Enslow said that the pressure scheme, churning with compressed air or dry-ice pressure, would be very helpful if the blockage were more physical than chemical —i.e., the back pressure would loosen up compacted sand or gravel. If the chokage be due to incrustations of calcite, or iron or manganese depositions, then the loosening with acid in some form would prove necessary in addition. In place of using strong acid the use of sulphur dioxide from cylinders had been suggested. Fed as a gas to the bottom of the well, the mild sulphurous acid produced would serve to attack the carbonates, reduce the iron and manganese and peptize such deposits. The simplicity and safety of the scheme had an appeal over the handling of strong acid. Compressed air churning could well be used in conjunction with the gas feed to force the acid back into the bottom gravel or sand.

Mr. Enslow also described briefly a very simple expediment employed in converting an elevated storage tank into an iron removal unit as well as a storage tank on small well supplies. At the supply well a proportional diaphragm pump feeder injects a solution of high test hypochlorite and caustic soda. The soda absorbs all free carbon dioxide and raises the alkalinity to the pH value at which corrosion is inhibited as evidenced by the marble test or the Enslow Stability Indicator. The hypochlorite charge is then adjusted by gradual increase in amount dissolved in the caustic solution until all iron, or sulphide or manganese is oxidized. This point is detected by the flash residual chlorine test. The water so treated goes through a natural flocculation without the aid of aeration. The central riser in the tank is extended to terminate 4 feet or more above bottom to provide a quiet sludge zone. If the tank is filled at night, by morning the clarification is completed and only the iron freed upper water is drawn from the tank and the sludge zone is not disturbed. As frequently as required sludge is bled from the tank bottom through a small separate line to waste. Mr. Enslow credited this development to M. C. Smith and H. E. Lordley of Richmond, Va., in connection with a small supply owned and operated by the city.

National Water Week?

The question of naming a National Water Week was presented by W. W. Brush, editor of *"Water Works Engineering,"* for the purpose of focusing more attention on the water utility in the U. S. After some discussion the Section endorsed in principle the establishment of a National Water Week.

A brief discussion of measures taken by Water Departments in the way of sabotage prevention and protection of water supply systems against attack, closed the meeting.

Nothing new that has not frequently been repeated in earlier meetings came from the discussion. Mr. Gibson stated that all of Charleston's station engineers had been made State Constables and he believed flood lighting to have its value. Plant visitors are carefully scrutinized at the front entrance—however, the back and side entrances were pretty broad, too, if anyone committeed to doing damage should want to get in bad enough.

Secretary Jordan commented that all reports to date from England and other countries under attack had indicated no planned attack on water supply works or other essential utilities. The damage had been suffered from chance hits only.

President Howard pointed out that visitors had been completely excluded from Canadian plants; that all receipts of gasoline and lubricating oils were being carefully inspected, and all parcels delivered to the plant are opened at the gates.

WATERING FALLACIES

During the approaching Summer and early Fall, if it is dry and results in throwing a heavy peak load on water systems due to the custom of lawn sprinkling in the late afternoon and early evening, distribution of what is printed below may prove helpful in getting consumers to do much of their sprinkling during the day rather than delay it until evening.

The little article captioned "Watering Fallacies" appeared in a pamphlet on "Lawn Care" published by a large producer of lawn grass seeds—O. M. Scott & Sons Co. of Marysville, Ohio. Certainly this firm would not advise its customers erroneously, and coming from such a dependable source the message has much more meaning to the general public than otherwise.

WATERING FALLACIES

Many people inquire if chlorine and other chemicals used in purifying city water are harmful to grass. If water is suitable for human consumption or even for laundry purposes, it is not likely to hurt grass. It is doubtful if enough such water would ever be put on a turf to cause any appreciable concentration of chemicals. The lime in some water may tend to alkalinize soils but never harmfully so.

Some folks seem to think that grass plants absorb water through their blades and stems. This is possibly due to the fact that grass looks so much fresher right after watering. Actually grass can make use of moisture only by taking it up from the soil through the root system so water must be put into the ground where it becomes available to the roots.

There is widespread belief that to water during the heat of the day may result in "scalding" the grass. In fact the water has a tendency to cool rather than burn. Those who say that water drops act as millions of small lenses magnifying the heat of the sun, forget that the drops evaporate before any such burning could result. If damage to the lawn occurs after watering, look to some other cause. The important thing is to put on the right amount of water and this may be done at any convenient time of the day.

(Incidentally, every consumer with a lawn should find much of interest and value in these monthly publications mailed out gratis.

Silence is Golden

WITH THE

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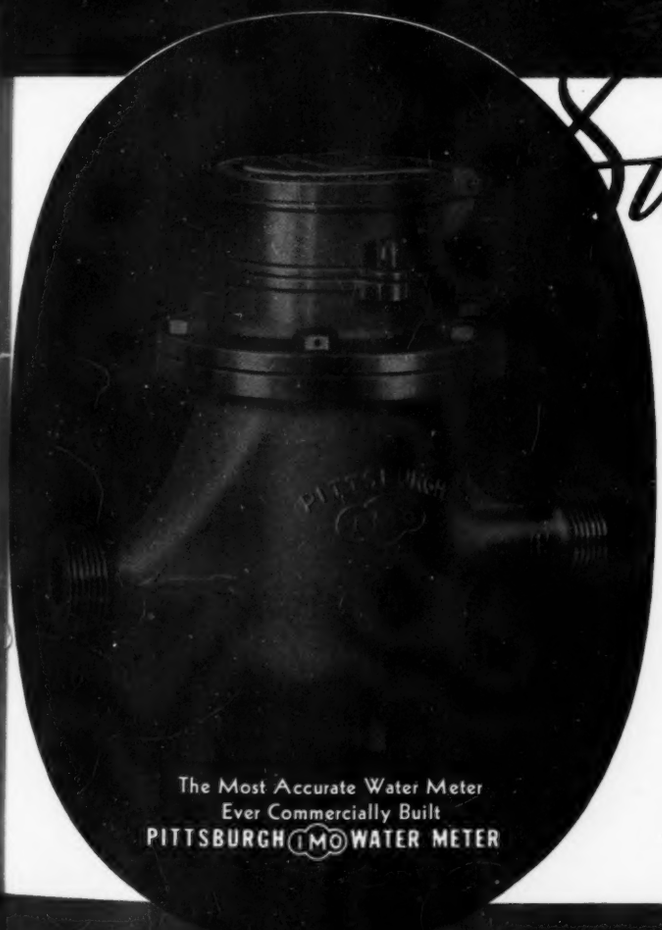

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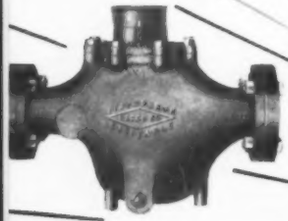

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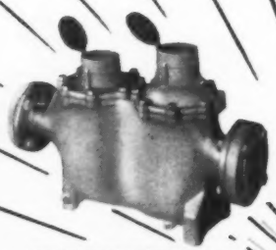

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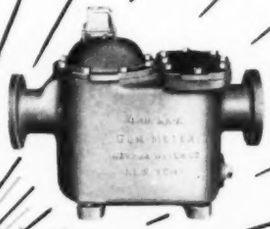

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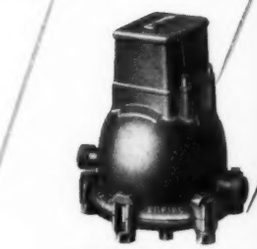

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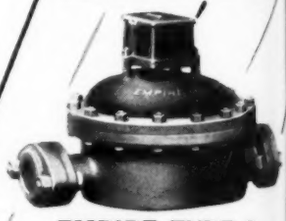

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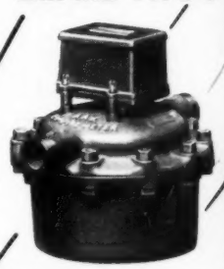

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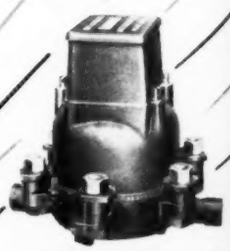

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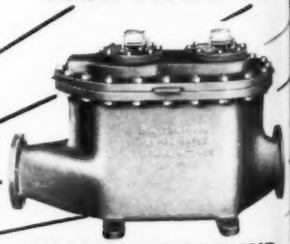

EMPIRE COMPOUND

A Type and Size For Every Requirement or Preference of Waterworks Men

RESERVOIR SILTING

And Factors of Importance in Silting Control

By CARL B. BROWN
Head
RESERVOIR SECTION
SOIL CONSERVATION SERVICE
U. S. DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

MUCH of the public water supply of the United States comes from impounding reservoirs. More than 2,600 dams have been constructed in this country to impound water for public or industrial supply at a cost of more than $463,000,000 exclusive of appurtenant water works and distribution lines. About 25,000,000 persons or nearly 20 per cent of the population of the United States obtain its domestic water from these storage reservoirs.

Not only do such great cities as New York, Boston, Baltimore, Birmingham, Dallas, Denver, Seattle, San Francisco, and Los Angeles depend on reservoir systems, but innumerable smaller cities and towns throughout the country derive their water from such sources.

Among the more important, and one of the least considered, problems in the development and maintenance of impounding reservoirs is the loss of storage capacity by silting. Examination of a number of textbooks on water-works engineering written during the last ten years reveals only a very cursory treatment of this problem, despite the fact that engineers, from time to time for many years, have called attention to silting problems in this or that water-supply reservoir, as well as in reservoirs constructed for power, irrigation, recreation, and navigation.

Agricultural specialists long ago recognized that exploitative deforestation, forest fires, overgrazing, cultivation of oversteep slopes, improper methods of tillage, and other unwise agricultural practices caused greatly accelerated soil erosion, which resulted in a large increase in the sediment load of streams.

Moreover, it has long been taken for granted that a cause and effect relationship must exist between accelerated soil erosion and high rates of reservoir silting. Steps have been taken only recently, however, to determine the extent to which the tremendous investment in our reservoirs is being affected by silting, the degree to which present rates of silting are caused by acceleration of erosion, and the measures that may be adopted to decrease silting where it is causing excessive damage.

The Author

Serious Studies of Silting Begun Only Recently

In 1935, Congress created the Soil Conservation Service as a permanent agency of the United States Department of Agriculture in order "to provide permanently for the control and prevention of soil erosion and thereby to preserve natural resources, control floods, *prevent impairment of reservoirs*, etc. . . ." (5). In conducting the research authorized by this act, the Soil Conservation Service established a Sedimentation Division to determine the character and extent of downstream damages resulting from soil washed from upland slopes. And, more importantly, the nature and location of control measures required to ameliorate these damages. Water supply reservoir silting has become one of the principal problems being investigated by this Division. The study of this problem includes inventorying the reservoir resources of the country, determining by surveys of representative reservoirs the amount and rate of damage by silting, establishing the relationship of silting to soil erosion and to the transportation of sediment within the watershed, and consideration of the methods available for combating the silting damage.

Survey Procedures

Two types of reservoir surveys have been made. The reconnaissance survey has been designed to determine the approximate rate of loss of storage capacity, and consists of measuring the thickness of sediment at from 15 to 50 or more well-distributed locations in a reservoir by means of a simple measuring device known as a spud (Figs. 1, 2). Using simple formulas, the ratio of sediment volume to the original storage capacity may be estimated. Adequate reconnaissance examinations of moderate-sized reservoirs, up to about 10,000-acre-foot capacity, can be made by a specialist in this work in one day with one helper and a motor

The "Grand Canyon" of Elk City

This picture shows what silting did to what not many years previously was the water supply reservoir of Elk City, Oklahoma. It shows another thing too—that once silted not even a dam failure will scour out the deposit of silt, much less sluicing through dam gates.

boat. The results provide a satisfactory basis for estimating the order of magnitude of the remaining life of the reservoir, such as 10, 20, 50, or 100 years.

The detailed reservoir survey, on the other hand, involves a standardized engineering measurement of the original and present capacities of the reservoir, as well as the sediment volume. A complete description of the methods used in making the detailed surveys is contained in a bulletin of the United States Department of Agriculture[1] which is available to any who may desire this publication.

These detailed surveys differ from reconnaissance surveys not only in their much higher degree of accuracy, but also in the fact that all survey stations are monumented to permit future repeat surveys on an exactly comparable basis, thus providing checks on the progress of sedimentation at such interval of time as may be considered desirable. Furthermore, the data from these detailed surveys are of sufficient accuracy to be used in calculating indices of sediment production or net erosion from the watershed in terms of cubic feet per acre annually, or in any similar units. These computed "indices of erosion" may be used by extrapolation in estimating the probable rates of sediment delivery from adjacent or similar watersheds, and are considered more accurate for this purpose than are short-term records of the suspended load of streams determined by sampling. Detailed surveys require the services of four or five men, and take up to three weeks on reservoirs of less than 10,000-acre-foot capacity.

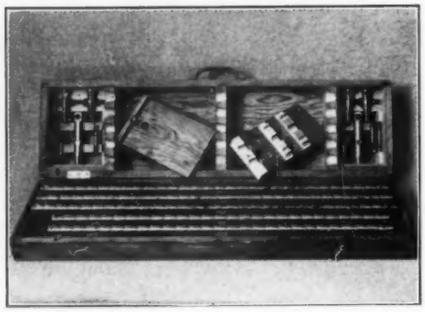

Fig. 1.—Sectional Spud and Points
Used in surveying to sound silt accumulations and quality of deposits caught in the cups.

450 Reservoirs Surveyed—151 on Water Supplies

To date (May, 1941) data have been obtained on silting in about 450 reservoirs in 36 States, about four-fifths of them surveyed by the Soil Conservation Service during the last six years. Detailed surveys have been made on about 150 reservoirs, and reconnaissance surveys on the remainder. Of the 450 reservoirs on which silting data are available 151 are used primarily for public-water supply.

Figure 3 shows in graphical form the rates of silting in all water-supply reservoirs for which the Soil Conservation Service has made detailed surveys. These reservoirs represent a fair cross section of the whole country, except that the New England States and the Pacific Northwest are not proportionately represented. These sections have generally less serious reservoir-silting problems than do other sections. The records show that slightly more than one-third of the reservoirs surveyed are losing their capacity at a rate of more than one per cent annually, while slightly less than one-third are losing from one-half to one per cent, and an equal number less than one-half of one per cent annually.

In order to analyze the significance of the silting problem in terms of the average life of all water-supply reservoirs in the country, three assumptions are made:

(1) That decrease of capacity to 20 per cent of that originally provided will, on an average, terminate the useful life of a reservoir.[1]

(2) That the rate of silting will remain generally uniform until 80 per cent of the storage capacity is gone.

(3) That the 151 water-supply reservoirs on which data are now available represent a fair cross section of conditions over the whole country.

Based on these assumptions, it appears that, as a result of silting alone, 21 per cent of the Nation's water-supply reservoirs will have a useful life of less than 50 years; another 25 per cent, 50 to 100 years; whereas only 54 per cent will provide enough storage to suffice for present requirements (not the estimated future needs) 100 years hence. (See comments in footnote indicative of the conservancy of this statement.—Ed.)

What Can Be Done About It?

So much for the magnitude of the silting problem. What, now, can be done to lessen the present rate of damage and minimize this hazard, which is not only impairing the enormous investment already made in reservoirs, but threatens to destroy the irreplaceable and virtually invaluable reservoir sites?

Reservoir Cleaning Too Costly

A common proposal has been to clean out the impounding reservoir by some engineering method such as pump dredging, sluicing through the dam, or dragline excavation. Although cleaning out may be the only alternative in rare instances, it has been widely found to be too costly

And in the East Too!
Near Spartanburg, S. C., what was once a useful mill pond is now mostly a cat-tail ranch. One of Spartanburg's water supply reservoirs of earlier years suffered the same consequences. Abandonment is less costly than dredging in such cases.

*The assumption of 80 per cent of the original capacity may be too conservative. An investigation of A. N. Garin, Economic Research Division, Soil Conservation Service, of 17 water-supply reservoirs in the Trinity watershed, Texas, indicated a range from 38 to 85 per cent and an average of 60 per cent. If it were assumed that 60 per cent of the original capacity would terminate the useful life of the average reservoir, then 32 per cent of the Nation's water-supply reservoirs would be useless in less than 50 years and another 22 per cent in less than 100 years.

for general consideration even if physical conditions provide some place for disposal of the sediment where it will cause no further harm. For example, the estimated average original cost of storage space in the water-supply reservoirs of Maryland and Pennsylvania is $51 per acre-foot, or slightly more than three cents per cubic yard. The cost of removal of any considerable quantity of accumulated sediment by any available engineering methods may be expected to be 5 to 50 times as much per cubic yard of reclaimed storage.

The most extensive reservoir-dredging operation undertaken in the past few years was that on White Rock Lake at Dallas, Tex., the use of which as a source of water supply was discontinued in 1928, partly because the greater demands of a growing city required a larger reservoir, but also, in no small measure, because silting reduced its capacity by more than 15 per cent in 18 years. After 1928 White Rock Lake rapidly became a popular recreational spot and has enhanced the value of nearby property by an estimated $10,000,000. By 1937 silting and unhealthful swamping of a large area in the upper part of the lake led to construction of an 8-inch hydraulic dredge for the purpose of cutting channels through the reservoir delta and dumping the sediment on islands which could be beautified for recreational use. Records of this dredging show an operating cost of 12 to 13 cents per cubic yard moved. Including capital investment, depreciation, and supervision, the total cost has been estimated at about 25 cents per cubic yard. It should be remembered, moreover, that sediment was not moved out of the reservoir, but was moved only a few hundred feet on to the silt islands.

Costs of clearing debris basins in southern California by power shovel and trucking the material for not more than one mile have averaged 30 cents per cubic yard. Experience of the Soil Conservation Service in excavating even small farm ponds has indicated minimum costs of 10 to 15 cents per cubic yard with drag scraper and team where the excavated material was dragged or hauled at most only a few hundred feet on to the dam. Costs on large-scale river- and harbor-dredging projects of the United States Army Engineers have ranged from averages of 10 to 25 cents per cubic yard for different sections of the country.

Fig. 2.—Survey Party of the Soil Conservation Service at Work on the Water Supply Reservoir of Dallas, Texas

Man holding sounding spud pointing to mud mark revealing total depth of deposit, and second man is pointing to division line between new silt above and old deposits below.

Sluice Gate Flushing Of Little Help

Efforts to flush sediment out of an impounding reservoir by opening sluice gates or other outlets of the type built into dams in this country have succeeded in removing only a small fraction of the accumulated material, actually less than five per cent in cases of record, except where the use of the reservoir was discontinued for one or more years during

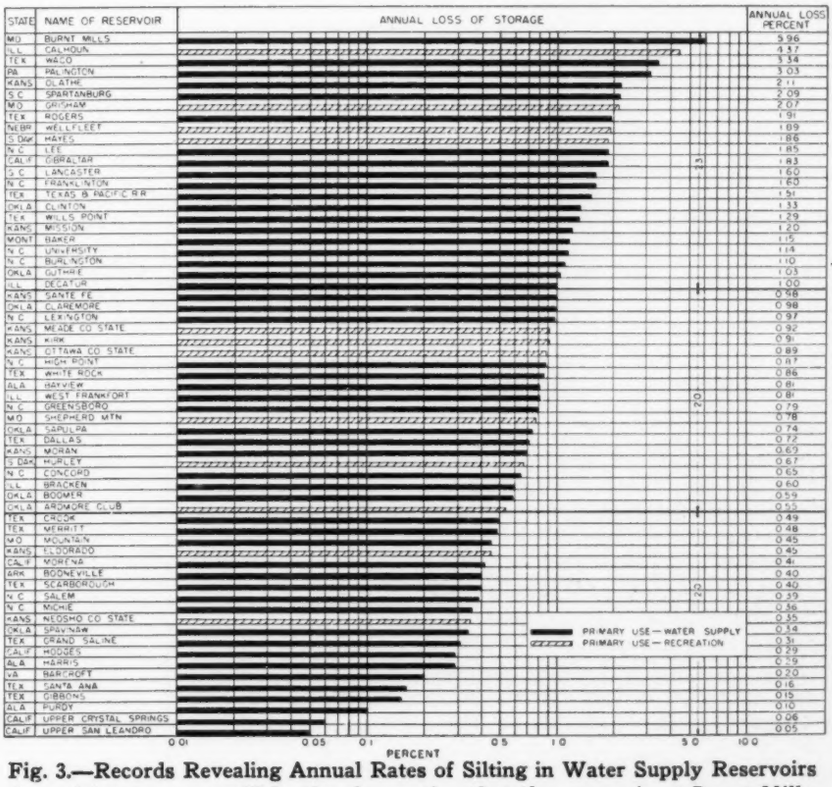

Fig. 3.—Records Revealing Annual Rates of Silting in Water Supply Reservoirs

Surprising to many will be the observation that the reservoir at Burnt Mills, Md., tops the list in annual loss of storage capacity in per cent. Also that Kansas, Texas and Oklahoma have silting records but little more pronounced than the Carolinas.

A Mill Reservoir Near High Point, N. C.
Now worth but little to the owners. This picture also reveals the futility of attempts at sediment flushing by complete rapid draw-downs.

which stream action was able to carve out more of a channel through the sediment, and reestablish its original stream grade.

Three Feasible Approaches To Silting Control

The three generally feasible approaches to reservoir-silting control are (1) adequate consideration of the silting factor in the original location and design of the dam, (2) a plan of water release designed to vent the largest possible amount of sediment before it has an opportunity to deposit and compact, and (3) watershed protection through land purchase or cooperation with land owners to control soil erosion.

In considering location and design, it is obvious that if reservoirs of equal size could be constructed in either of two watersheds at approximately the same cost, including cost of bringing the water to the distribution system, that watershed having the least erosion (likewise, sources of pollution) should be chosen. Water-supply studies in recent years have generally given much weight to the factor of pollution, but they have seldom evaluated adequately the problems created by the sediment load of the streams. Two types of damage arise from this sediment load, namely, the loss of reservoir-storage capacity and the increased cost of clarification in water treatment.

In a recent study of the effects of soil erosion on the costs of public water supply in the North Carolina Piedmont section, Garin and Forster[3] have estimated the annual capital loss in 22 municipal reservoirs, resulting from the lost utility value by silting, at $32,000. The present worth of this sum, at rates of interest of 4½ to 6 per cent being paid on the bonds issued for these developments, is $580,000. It might be argued that any sum up to this gross amount could be spent for the prevention of silting alone. Taking the municipal reservoir at High Point, N. C., as a typical example, these economists computed an annual capital loss of $5,224 based on a measured annual storage depletion of only 0.77 per cent, a moderate figure for this region.

In addition, Garin and Forster found an increase in the cost of water treatment with increased sediment load. The average cost of treatment, including overhead charges and amortization of plant and equipment, is about $70 per million gallons. For treatment alone the cost is $27 of which $5 is for cost of chemicals. The relation of the consumption of alum, which accounts for the greater part of chemical cost, to turbidity is shown in Fig. 4. They have estimated that a reduction in the suspended load of the streams by 30 per cent, a modest expectation from an adequate erosion-control program, would result in an average saving of $1.50 per million gallons in the cost of treatment and that other savings resulting from smaller capital outlay for settling basins and filter plants, and from reduced costs of flushing and other plant operations would eventually bring total savings to $7 per million gallons of $94,500 annually for all towns in the North Carolina Piedmont that have impounding reservoirs. Capitalized at 5 per cent, the present worth of a 30 per cent smaller sediment load would be $1,890,000.

These figures argue for both proper consideration of watershed characteristics in selecting the site of a reservoir and for erosion control on the watersheds of existing reservoirs.

Importance of Reservoir Capacity; Water Shed Area Ratio Evident

A second aspect of location and design is the development of a favorable ratio between the capacity of the reservoir and the size of its tributary drainage area. *This relationship is*

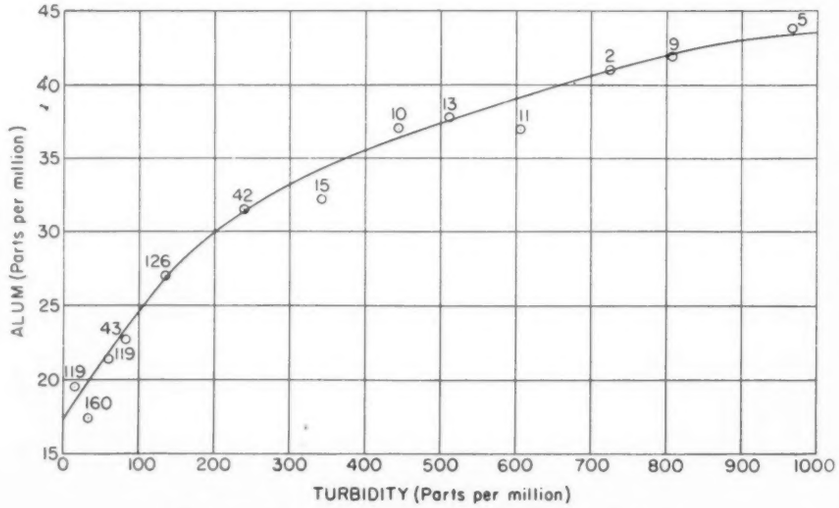

Fig. 4.—Relationship of Turbidity to Alum Use
This composite curve for 12 representative filter plants in North Carolina indicates the high cost of turbidity accompanying cumulative silting losses.

one of the most important factors governing the annual rate of storage depletion. Table 1 shows that the average rate of silting of representative reservoirs in the eastern states increases as the average storage capacity per square mile of drainage area decreases. These data indicate that the average reservoir should hold at least 75 acre-feet of water per square mile in order to have a safe life of 100 years. (This, assuming the useful life terminates with a loss of 80 per cent of the original storage.) The significant fact that only 34 per cent of these representative eastern reservoirs have a ratio this high leads to the conclusion, from the standpoint of silting, that either the reservoirs are too small, or the watersheds are too large. Study of the operating histories of these reservoirs reveals that a majority lost water by spillway discharge during 6 to 10 months or more in most years, and are seldom drawn down more than a few feet below spillway level. It is, therefore, apparent that smaller watersheds, in general, would have produced an ample water supply and, at the same time, suffered less depreciation from siltings.

Studies Revealing the Behavior of Highly Turbid Waters in Simulated Reservoirs

Demonstrating the pronounced underflow of highly turbid (muddy) waters entering reservoirs only to appear shortly at the dam due to underflow short circuiting. With a floor slope of 8% the velocity of the sediment "head" was better than 123 ft. per hour. On the right the underflow of turbid water is riding over a submerged coffer-dam. Rather effectively shows why silt deposits are so often pronounced at the dam face; also how bottom gate opening during freshet should be of marked benefit.

TABLE 1.—RELATION OF ORIGINAL STORAGE PER SQUARE MILE OF DRAINAGE AREA TO AVERAGE ANNUAL DEPLETION OF STORAGE IN THE EASTERN STATES

Original storage per square mile of drainage area *Acre-feet*	Number of reservoirs	Per cent of total number	Average annual depletion of storage *Per cent*
1-25	10	24	2.77
26-50	8	20	1.09
51-75	9	22	0.87
76-200	7	17	0.39
Over 200	7	17	0.28
Total	41	100	

Dam Openings Deserve More Thought in Design

As a third consideration, adequate attention should be given in the design to the number, location, size, and manner of control of openings in the dam through which water can be released. The reason for this is explained below.

Lastly, reservoir basins developed off the main channels and supplied by water diversion have lower silting rates than reservoirs of corresponding size on the main stream, because diversion can be controlled to permit only normal stream flow to enter the reservoir and to bypass heavily sediment-laden flood flows downstream. Where topographic conditions permit (and this will not be in a majority of cases), the development of off-channel reservoirs should be seriously considered, even though higher costs per unit of storage are involved initially.

The second approach to silting control is through improved practice in water release at the dam. Considerable data have been collected in the last five years by field observations and laboratory experiments on the movement of the finer particles of the sediment load of a stream through a reservoir. These studies have revealed the widespread occurrence of density currrents or underflows of heavily sediment-laden waters from the upper end of a reservoir to the dam. Such currents are caused by the tendency of sediment-laden waters entering a reservoir to sink and move along the bottom under the relatively clear water already in storage. The underflow current is commonly characterized by differences in temperature and dissolved matter as well as by sediment content and can be readily recognized through sampling procedures. First observed and more carefully studied in some of the large western reservoirs,[2, 4] underflow is known to occur, but is believed to be common in all sections of the country. In fact, such occurrences have been reported in Lake Lee at Monroe, N. C.; Lake Murray, near Columbia, S. C.; Lake Issaqueena near Clemson, S. C.; Norris Reservoir in Tennessee; Lake Dallas, Tex.; and in Leesville Reservoir, Leesville, Ohio. Lake Issaqueena, although constructed primarily for recreational purposes, is typical in size and other characteristics of the average water-supply reservoir of the Southeast.

Measurements were made in 1940

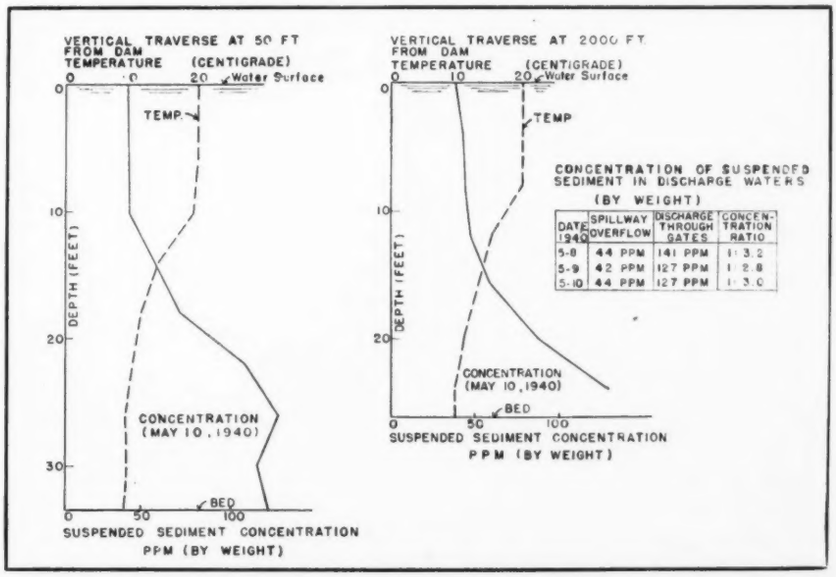
VERTICAL TRAVERSE AT 50 FT FROM DAM
TEMPERATURE (CENTIGRADE)
0 0 20 Water Surface
TEMP.
DEPTH (FEET)
CONCENTRATION (MAY 10, 1940)
BED
0 50 100
SUSPENDED SEDIMENT CONCENTRATION PPM (BY WEIGHT)
VERTICAL TRAVERSE AT 2000 FT FROM DAM
TEMPERATURE (CENTIGRADE)
0 10 20 Water Surface
TEMP
CONCENTRATION OF SUSPENDED SEDIMENT IN DISCHARGE WATERS (BY WEIGHT)
DATE 1940 | SPILLWAY OVERFLOW | DISCHARGE THROUGH GATES | CONCENTRATION RATIO
5-8 | 44 PPM | 141 PPM | 1:3.2
5-9 | 42 PPM | 127 PPM | 1:2.8
5-10 | 44 PPM | 127 PPM | 1:3.0
CONCENTRATION (MAY 10, 1940)
BED
0 50 100
SUSPENDED SEDIMENT CONCENTRATION PPM (BY WEIGHT)

Fig. 5.—Graphic Plotting Revealing Relationship of Depth to Temperature and Sediment Concentration from Studies at Clemson, S. C.

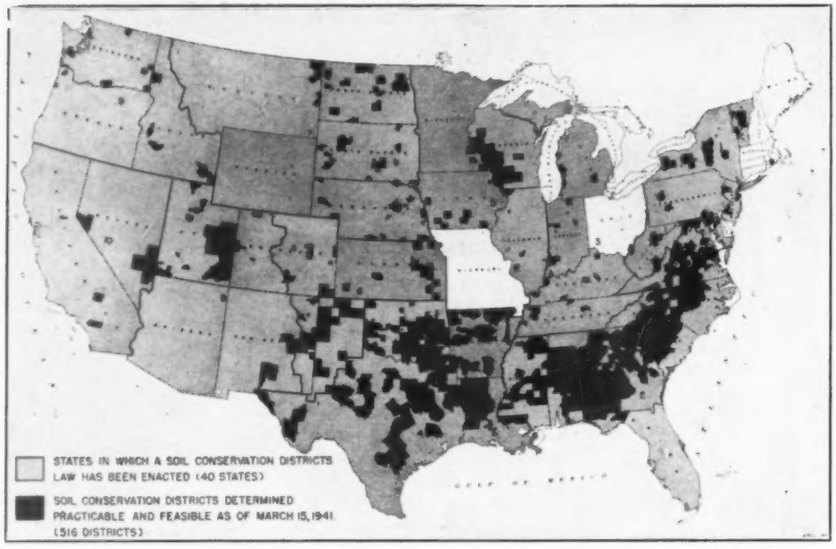
STATES IN WHICH A SOIL CONSERVATION DISTRICTS LAW HAS BEEN ENACTED (40 STATES)
SOIL CONSERVATION DISTRICTS DETERMINED PRACTICABLE AND FEASIBLE AS OF MARCH 15, 1941. (516 DISTRICTS)

Fig. 6.—Progress in Organization of Soil Conservation Districts as of March 15, 1941
(*Many districts organized include municipal water supply sources.*)

of temperature and sediment content at two locations in this lake and samples were taken of the spillway overflow and discharge through a gate in the bottom of the dam. Figure 5 presents the results of part of these measurements which indicate that higher sediment concentrations existed in the lower levels of the lake at the time of sampling and that, on an average, three times as much sediment was carried past the dam by water released through the bottom gate as in the water passing over the spillway. Moreover, these data show only the residual effects of density currents, as no actual flows were in progress at the time of sampling. When such flows are underway, the difference in sediment concentration between water at the surface and at the bottom, even in reservoirs prevailingly turbid, would be very much larger. This residual effect, due to slow settlement of fine sediment, may last for days or weeks and the same effect probably exists without density currents simply as a result of normal settlement of fine particles from a turbid inflow. There is much evidence pointing to the value of maintaining a sampling program to determine surface and bottom sediment concentrations at the dam in all water-supply reservoirs. If suspended sediment distribution in a vertical at the dam is found to be similar to that at Lake Issaqueena, as much as possible of the waste water should be released through whatever outlets may exist near the bottom of the dam. Conversely, water taken from the reservoir for consumptive use should be withdrawn as closely to the surface of the lake as possible to obtain that water having the least turbidity and requiring the lowest cost of treatment, provided, of course, the turbidity of the surface water is not so low as to increase cost of treatment by certain filtration practices, or that algae blooms do not render taking of supply from greater depths more desirable on the score of taste or odor minimization.

The percentage of the total incoming sediment load that might be vented from the reservoir through proper gate control will differ greatly. In this consideration much will depend upon the mechanical composition of the incoming sediment and also the size and shape of the reservoir, since the latter influences the movement of water through it, and the type and location of gates available for water release. The problem should be carefully studied on all reservoirs where sediment is a factor. It should be borne in mind that the difficulty and cost of removing sediment from an impounding reservoir depends upon the extent to which the sediment has settled and compacted. Once the sediment has compacted to a degree represented by a weight of 40 to 50 pounds of dry material per cubic foot of deposit, the cost of desilting makes its removal economically infeasible in most cases.

Another Post-Mortem—"Black Mud"
In one year the 300 acre-foot City Lake of Osborne, Kansas, was a complete loss for water storage. Sewage men will see a similarity between sun dried black Kansas mud and digested sewage sludge.

The Factor of Most Likely Permanent Value

The third major factor in silting control—the control of soil erosion and sediment movement on the drainage area—is likely to be the most useful to the largest number of waterworks operators, and is unquestionably the most enduring in its effects.

Two plans of action to obtain better control on the drainage area are open to the city or water company: (1) The area might be purchased in its entirety, further use of the land prohibited or adequately restricted, and the most effective of all erosion control—complete revegetation with trees and grasses—carried out with the assistance, if required, of State and Federal conservation agencies.

For immediate supplementary protection until vegetation becomes effective, small dams or sediment barriers may be useful. This plan not only leads to the minimum of sediment production, but also does most to inhibit pollution. Numerous cities in North Atlantic States, for example, have long ago seen the wisdom of this course and a number of splendidly protected watersheds are now in existence. In some instances the cost of purchase and protection of the watershed has exceeded the cost of the reservoir itself, but has been considered fully justified as long-term insurance.

Unfortunately, the cost of complete watershed purchase in many areas has been prohibitive, and until five years ago, cities in such areas were confronted with the losses involved in reservoir silting without having feasible means of effecting a control of the sources of sediment. Since 1936, however, a new avenue toward better watershed protection has been developing in the Nationwide Soil Conservation Districts' program.

The Soil Conservation District Movement Gaining

By April, 1941, the legislatures of 41 States had enacted soil conservation district laws, and 469 districts embracing more than 287 million acres of land have been organized (see Fig. 6). These laws, differing from each other only slightly in their provisions, are enabling acts which *permit* farmers and landowners to organize soil conservation districts to engage in cooperative action to promote soil and water conservation and to prevent local or occasional misuse of land by voting land use regulations upon themselves. The districts have the status of governmental subdivisions of the State.

The procedure for the organization of soil conservation districts is strictly democratic from beginning to end. A petition signed by a specified number of farmers and landowners (which can also include municipalities and corporation) is sent to the State Soil Conservation Committees at the State college of agriculture. The State committee holds a public hearing. If a genuine desire and need for a district is manifested, the State committee defines the proposed district boundaries and gives notice of a referendum to determine the sentiment of all persons within the prescribed area qualified under the districts' law to vote on the issue. If the proposed formation of the district is voted upon favorably, the State committee appoints two supervisors who obtain a legal certificate of organization and set a date for the election of three additional supervisors from among the voters in the district. When the board of supervisors is thus duly organized, it may consider and approve plans for erosion-control activities, may enter into cooperative agreement with Federal and State agencies, accept technical services, allotments of funds and labor, and may purchase erosion-control machinery, equipment, and materials such as seed, lime, or fencing.

In several States, plans are now materializing for the cooperation of certain towns and cities, that own municipal reservoirs, with organized districts in the development of erosion-control programs designed to effect the largest practicable degree of sediment reduction in the streams supplying the reservoirs.

Among the conservation practices most widely recommended for erosion control are (1) proper crop rotations, (2) plowing on the contour, (3) terracing, (4) strip cropping, (5) development of vegetated field drainage ways, (6) check dams, (7) reforestation and fire protection, and (8) grazing control.

These measures are applied mainly to the usable—the productive—land of the farm unit. There are other sources of sediment in many watersheds, however, which are often extremely hazardous to the downstream reservoir, but perhaps less dangerous to the individual farmer. These sources are erosion on stream banks, erosion of the ditches and fills of roads and railroads, gully erosion on land abandoned or unproductive for agriculture, and industrial wastes, especially from coal mining. The treatment of these sources is sometimes expensive, and the individual farmer may be economically incapable of controlling them even if he feels justified in doing so, but the cooperation between farmer and municipality or water company often can accomplish, to mutual benefit, that which either one alone could not undertake.

How Water Supply Interests May Benefit

It seems particularly appropriate, therefore, that water supply interests, where they are confronted either with significant reservoir silting or excessive purification costs, should be concerned with developing cooperative relations with soil conservation districts while these organizations are still in their formative stage. If districts are not yet organized in any particular area, the county agricultural agent, the State director of extension, or the State coordinator of the Soil Conservation Service at the State college of agriculture, will be glad to outline ways in which the water supply interests might assist in initiating or developing such districts and in cooperating with them. It may be anticipated that in many areas the addition of services and materials by the city or water company to the resources of the farmer would achieve a degree of erosion control and watershed protection not only of direct benefit in excess of cost to the city, but of even greater indirect benefit through increasing farm income and hence buying power of the community.

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Simple Test for Oil in Boiler Water

By W. F. SCHAPHORST, M.E.

Here is a valuable kink that was given to me the other day by a former chief chemist whose specialty is boiler waters and boiler water treatment. I am sure many others will be glad to know about it.

My chemist friend informed me that there is a really good and surprisingly simple test for oil in boiler water. Just take an ordinary clean test tube, fill it to a depth of about two inches with the feed water you want to test and shake it in your hand with your thumb over the opening for a few minutes. If at the end of a sufficient period there is an accumulation of bubbles on the surface of the water you can be almost positive that there is oil and plenty of it in the water. The test is really quite sensitive, and one which any boiler operator can perform with amazingly accurate results. If at the end of the shaking period there is no evidence of bubbles at all, you can be pretty sure that the amount of oil in the water is too little to cause any harm.

WATER WASTE SURVEYS AND LEAKAGE CORRECTION

By EDGAR K. WILSON
Chief Engineer, The Pitometer Co., Inc.
NEW YORK, N. Y.

WHEN man first emerged in human form he slaked his thirst at the streams and springs in the forests and plains. The water was pure and free—he had only to stoop down like the other beasts and drink his fill. Years —perhaps many ages—later a man smarter than the rest devised a vessel by which the water could be conveyed to a more convenient place and stored until it was needed. The water was still pure, but the labor of conveying it became a charge against its freeness. Later still man could not always live beside a stream or spring and a well was brought into being. The labor of digging the well was added to the labor of conveying the water which was still "free" and pure. The next step was that by which pumping engines connected with pipes furnished water to individuals in fast growing communities. The water was in many cases not as pure as it had been, and the money spent for installation of pumps and pipes, as well as the cost of keeping the pumps going, gave an actual money value to the delivered water, hitherto "free" from a money charge. With the addition of purification works, the money value has grown until now every effort is necessary to reduce or even hold at the present level the cost of water production.

In the old days when water was "free" except for the labor of lugging the buckets from the well, no check on its waste was used nor was there one necessary, since that labor in itself was a sufficient check; and if an individual were so ambitious as to carry unlimited supplies of water, the thriftiness of the wife would soon curb his energy when the requirements were reached for immediate uses or the available vessels were filled.

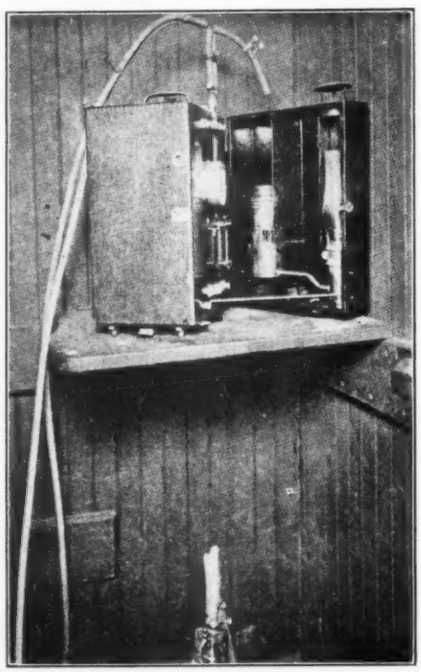
With the introduction of pumped water, however, this guard against waste in the houses was to a considerable extent relaxed, and with the installation of more modern plumbing, not only the use of water increased, but also the waste; so the water meter was devised, and the meter, where proper maintenance has been provided, has ever since been

The Author*

the most efficient watchdog against a careless or wilful water waste.

Again reverting to the early days, not much thought was given to the leakage from the mains, unless it came to the surface. Since many communities had no sewerage systems, the chances for the water to get away underground were far less than at present where sewer trenches and other sub-surface structures, in addition to the water trench, make easy paths for escape without showing any signs at the surface. Such leaks may and often do continue for years without discovery. Leaks do not tend to close up as time goes on —on the contrary they may become large enough to cause a serious drain on the system.

Where there is a station meter



A Photo-Recorder Set-up on the Job

which records the continuous flow of water, a large break will be automatically recorded and means may be taken at once to discover and remedy the trouble. Smaller leaks are likely to be hidden in the daily consumption, and as they grow in size and their number is increased, the total consumption of the system gradually creeps up and up until pumping capacities are found approaching their limit and pressures under heavy draft cannot be maintained.

Benefits to Be Derived from Leak Location Work

The location and repair of leaks, therefore, benefits a water works system in several ways:

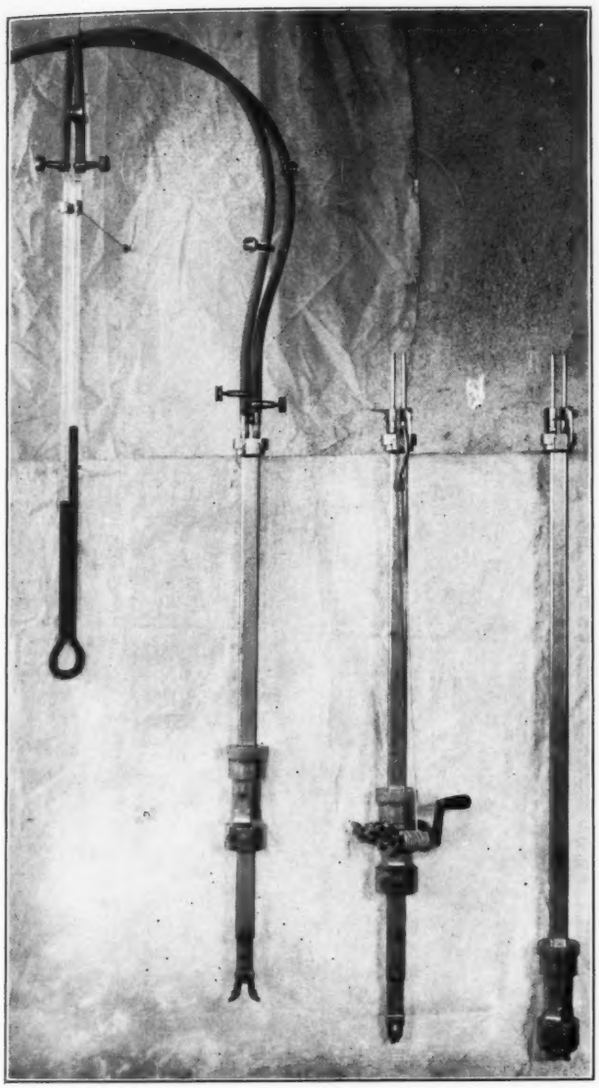
1. By conservation of the primary supply.
2. By saving treatment and pumping costs.
3. By postponing the installation of additional pumping equipment.
4. By eliminating or postponing the need for additional supply mains.
5. By eliminating the loss of head due to unnecessarily high velocities.
6. By elimination of possibilities of accidents due to undermining streets or buildings.
7. By increase of water and pressure available for fire fighting uses; also better residential pressures.
8. By decrease in the amount of water flowing into the sanitary and storm sewers.
9. By decrease in cost of handling an unnecessary amount of water in sewage treatment plants.

Other benefits may be observed in individual instances, but the above are sufficient to indicate that underground leakage is a matter of consequence, and one which should receive the attention deserved in the operation of every water works plant.

Methods of Detection and Elimination

The elimination of underground waste can be accomplished only by a thorough and painstaking survey of the entire system, *block by block.* Unless the water actually entering each block through the night hours

*Mr. Wilson, for several years a Trustee, was recently elected chairman of the New York Section of A.W.W.A.



Pitometer Rods and Manometer

of minimum consumption is measured, it is not possible to know certainly whether leakage exists. Such a measurement also eliminates the necessity of looking for leaks in blocks when it is shown that no flow exists which can not be accounted for as the reasonable consumption of such blocks.

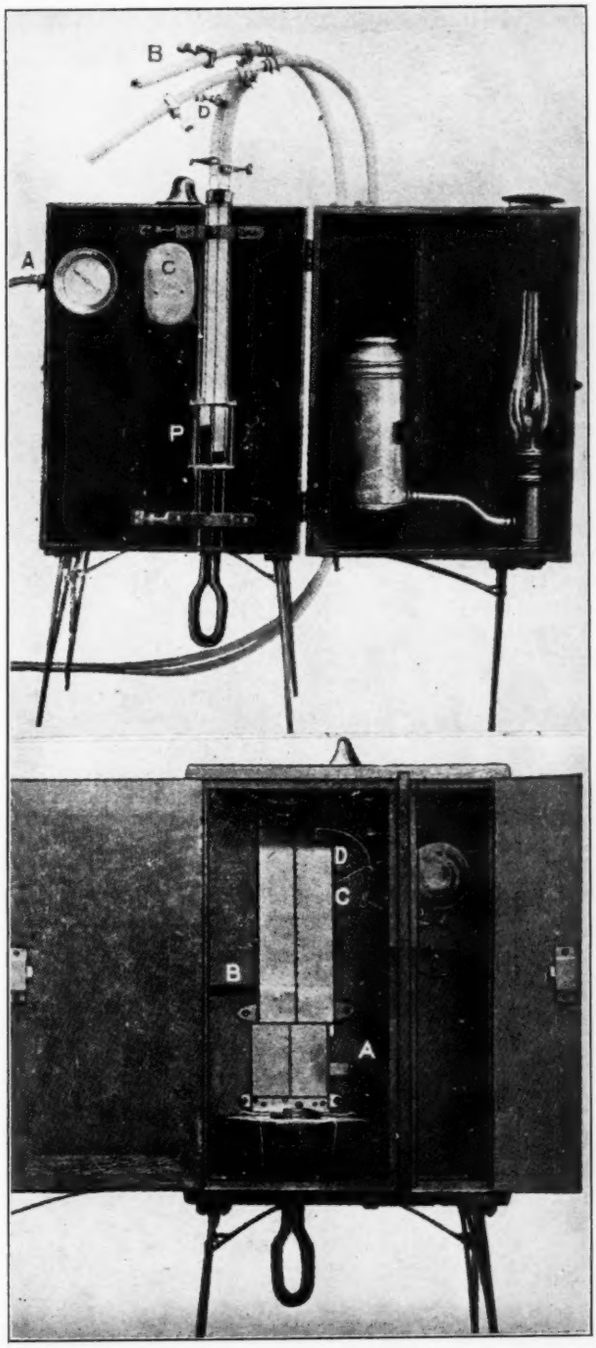
The Pitometer Survey

The best way of making these investigations is by a Pitometer water waste survey. Starting with the sources of supply or the pumping stations the survey tests the gravity supply lines for leakage, the pumps for slippage and efficiency, and the station meters for accuracy; and from that point conducts an audit of the water throughout the entire underground system.

The survey is carried on by measurements at gauging points which are installed throughout the system by inserting 1 inch corporation cocks at selected points in the mains, through which a Pitometer rod meter is introduced.

The Pitometer and Recorder

The Pitometer is an instrument based on the well known Pitot tube, adapted for the measurement of water in pipes under pressure. However, instead of having an upstream orifice facing the stream and a static orifice at right angles to the flow, the Pitometer has two identical orifices, one of which faces upstream and the other *downstream*. These orifices are connected to a glass manometer partly filled with a liquid of specific gravity higher than that of water, colored for easy observation of deflection, and also for the more effective photographing of flow records in the recorder, the description of which follows. With the apparatus entirely cleared of air, and the orifices set at the center of the pipe and aligned with the stream, a differential velocity is obtained which gives a deflection in the manometer. With the specific gravity of the indicating liquid known, the velocity and the rate of flow at the orifices can be readily determined for any given deflection observed or recorded.



The Photo-Recorder

The oil light makes a photographic picture of the differential levels in the manometer tube. The lower view is the recorder from the rear. The revolving drum carrying photographic paper has been removed from the left compartment to show the prism attachment.

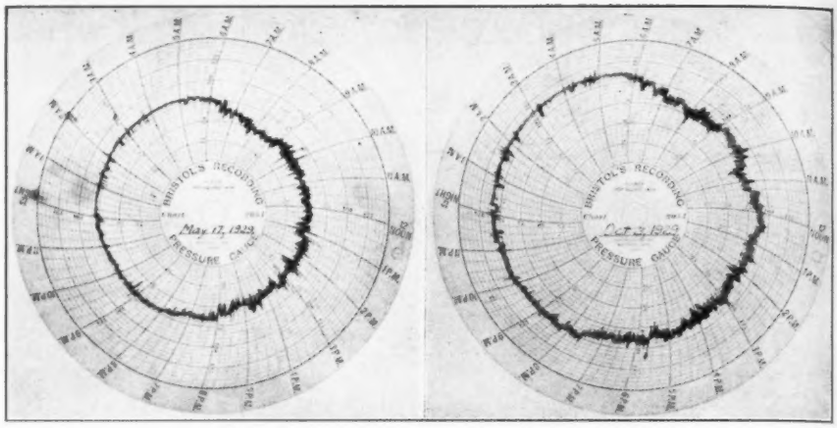
The "Pipe Factor"

To arrive at the quantity flow accurately a "pipe factor" is required. This factor is established by what is known as "traversing" the pipe. This is accomplished by taking readings on the manometer with the orifices set at various selected points across the pipe, fairly close together near the walls, and further apart as the center is approached. These points are plotted on cross section paper and a smooth curve drawn through them. Rings of equal area, representing the complete cross section of the pipe (usually five in number), are laid down on this curve. The manometer deflection recorded at the center of each ring is taken from the curve. The sum of the square roots of these deflections divided by the square root of the deflection at the center gives the essential "Pipe Factor." This factor is nothing more than the ratio of the mean cross sectional velocity of the water flowing through a particular main to the center velocity. Then, this factor is applied to the velocity of flow obtained with the Pitometer when the orifices are at the center of the pipe.

Determining Exact Flow

The actual diameter of the pipe is measured by use of a special caliper. With the area of the pipe thus determined and the average velocity across the pipe, determined as above, the quantity of water flowing is computed.

To record the deflections of the manometer liquid over a period of time, as, for instance, twenty-four hours, the Photo-Recorder is used. The manometer is clamped to this instrument and by means of a lamp a record is made of the varying deflections on a sheet of photographic paper. The sheet of recording paper is carried on a clock driven drum, the speed of which is controlled by different gears, so that one revolution of the drum may take place in 12, 24, or 48 hours as desired. After the record is developed, the flow at any time during the period of the run can be determined as well as the time at which it occurred. It is evident that several of these recorders can be set up at various points to attain simultaneous flow records, without the need for having observers on the job. Furthermore, the photographic records are the most dependable sort of records.



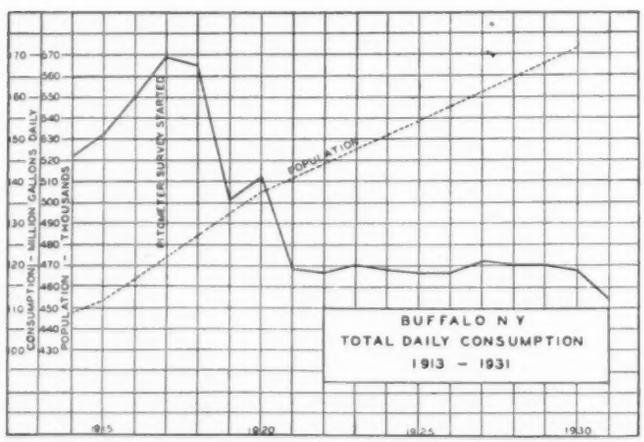
An Advantage of Leak Correction Illustrated

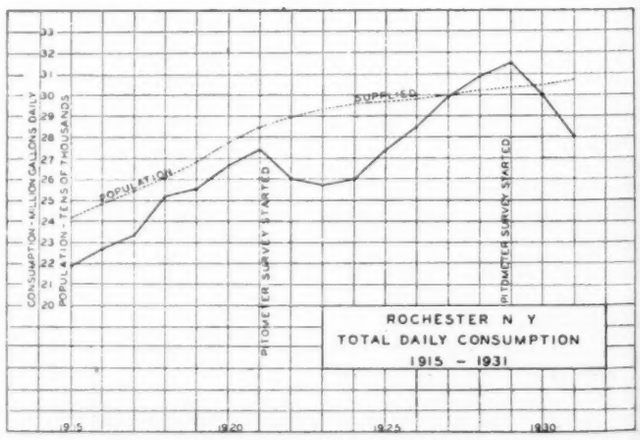
Frequently an important consideration is the recovery of pressures on the system as the result of leakage surveys and correction. These two pressure record charts (before and after), taken at an outlying point on the system, require no further explanation. Hidden in this record is that of reduced pumping costs in maintaining pressures, as well as in reduced volume pumped.

Making the Survey

As previously stated, a Pitometer survey should start at the pumping station or source of supply, after which district measurements are made for a period of twenty-four hours throughout the entire distribution system. The districts consist of areas, selected with due consideration of pressure and flow conditions. These areas must be subject to isolation by closing all mains leading into them except one, on which the Pitometer apparatus is installed. It is not usually the case that the main feeders from the station or throughout the system can be included in any district, since the closure of such mains will almost always so affect the pressures and supply that conditions would not be normal. These feeders are therefore tested by themslves without shutting down, or possibly with shut-offs of short duration only. Such shut-offs may be made during hours where no inconvenience of importance will result.

An inspection of the photographic record of the district measurement shows the relation of the total daily consumption and the important telltale minimum night rate of the district, which is a definite indication of the existence of waste. Since all important meters in the area under test are read during the time of flow measurement and checked for the time of minimum consumption, a





Two Rather Typical Records of Reductions in Water Pumped Following Water Waste Surveys

In the case of Rochester it is observed that following each survey the results of leakage correction and waste reduction are very evident.

correction of these amounts applied to the totals leaves the amount which must be charged to legitimate use, leakage—and, as in some cases, illlicit use through unmetered connections.

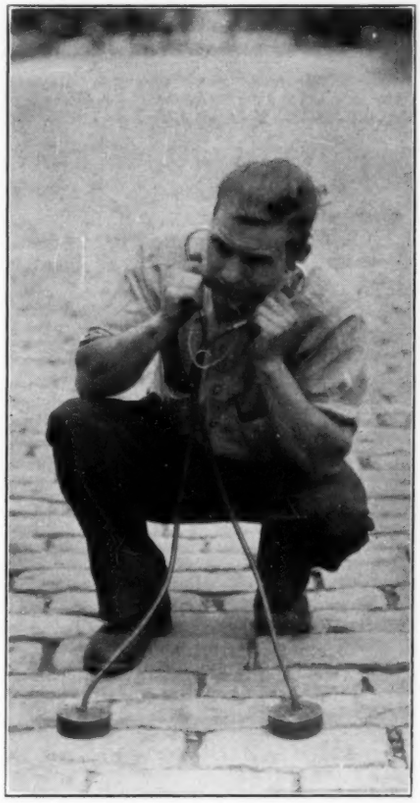
With this as a basis, the district is then subdivided during the night by closing off each block in turn. Any flow which was present in the block before it was shut off will be indicated by a drop in the deflection as recorded on the photographic chart. While making shut-offs each block is tested for tightness to be sure that all valves are holding, and that there is no unrecorded connection feeding into the block. During the subdivision the time of closing each valve is recorded.

With the subdivision chart completed, the times are plotted and the result of the shutting down of each block is observed, the deflection being measured from the photographic record as on the plain manometer.

Leak Location and Meter Checking Next

The results of the subdivision are carefully studied with reference to the amount of water which may be considered to be legitimate consumption. Night rates on large meters are taken into account and investigations are made in all blocks which still appear to have an abnormal consumption. These investigations are made with various listening devices placed on service stop cocks, hydrants, on water pipes inside of houses, or on the street surface; and leaks are located so closely that it is only very rarely that more than one hole must be opened for repairs.

During the course of the survey large industrial meters are tested in place without disturbance, so that their actual condition previous to the test is determined. This allows the test to be carried on under the actual working conditions of the meter which is not possible if the meter is removed to the shop for testing.



Listening for Water Leaks with Geophone.

Detecting Illicit Water Takings

Fire lines without meters are sometimes used for other purposes than fire extinguishing inside of manufacturing plants. While such uses, if only occasional, cannot always be detected except by long continued measurements, or by good fortune in happening to make the measurement at just the right time, if the practice is carried on at frequent intervals, the survey will furnish evidence so that back bills may be rendered for the unpaid-for water.

At the close of the survey a report is rendered which gives all details of the survey. A list of defective valves is furnished, which is of especial value, since ordinarily about ninety per cent of the valves in the system are operated during a Pitometer survey. Suggestions are also offered in regard to locations of new valves, and others matters which make for the more efficient operation of a water works plant. One highly important consideration is that pumping efficiencies are revealed, and design deficiencies are uncovered.

The location and repair of all leaks large enough to warrant the expense of the repair brings about important reductions in the cost of water service. It is usually the case, in fact, that the cost of the survey is covered by such reduction within a few months or a year.

A leak properly repaired is permanently closed, and the loss of water is eliminated at that point. However, in water works systems leaks are forever occurring. From some the water rises to the surface; and these leaks are at once repaired; but many do not manifest themselves and again the daily pumpage increases.

A Pitometer survey must not be considered as a leak prevention undertaking. New leaks may follow the survey, but at small expense periodical remeasurements of the districts will indicate where such have developend. In some of the larger cities five year programs have been instituted. These programs which cover some portions of the system each year have yielded very satisfactory results, both from the operating and economic points of view.

TOM SKINKER

New Water Commissioner of St. Louis

Thomas J. Skinker

After being "out of circulation" for the past two or three years in water works circles, Tom Skinker, former Engineer of Distribution in the Water Division of St. Louis, has just recently been returned to circulation, and at a much higher denomination. On June 12th he was called in by Max H. Doyne, the new Director of Public Utilities, and given the job of Water Commissioner at a salary of $7,000.

In 1937, after twenty-four years of service in the Water Division, Mr. Skinker resigned from his position as Engineer of Distribution. Up to that time he was a very active and popular member of the American Water Works Association, and his many friends will be as pleased as are we to hear that his keen ability and splendid standing in his city has won for him the commissionership.

Other changes made in the Water Division by the new Director of Utilities include the following:

John B. Dean becomes Engineer in charge of Supply and Purification, and E. E. Easterday becomes Engineer in Charge of Distribution.

NATION'S CAPITAL HOST TO MARYLAND-DELAWARE ASSOCIATION FIFTEENTH CONFERENCE

By HARRY A. FABER*
Associate Editor
WATER WORKS AND SEWERAGE

TWO hundred members and guests attended the conference of the Maryland-Delaware Water and Sewerage Association in Washington, D. C., on May 8th and 9th. A program of timely papers on the technical side was evenly divided between the two sanitary fields, water and sewage, with entertainment and inspection trips well provided for.

The Association was warmly welcomed by Major B. C. Snow, Assistant Engineering Commissioner of the District, who described the water supply and sewage treatment problems. These, he noted, increase in proportion to population—and Washington at present has a greater relative growth in population than any other U. S. city. In the decade, 1930 to 1940, population has increased some 180,000; an additional 60,000 has been added since the beginning of 1940; and it continues to increase at a rate of 16,000 a month. Keeping pace with water and sewerage facilities, for serving new housing construction, thus constitutes the present problem.

The Washington water system, including a gravity line runing nine miles from the river intake to the reservoirs, is constantly guarded. Passes are required for entrance to the filtration plants. An emergency supply is under construction as a precaution in case of need. Fortunately the new sewage treatment plant was completed before the present rate of population increase, and a new sewage gas engine has recently been added to the equipment to protect against power failure.

Federation Membership Meets Approval

During a business session a cordial reception was extended to C. A. Emerson, President of the Federation of Sewage Works Associations. He described the proposed plan whereby the Maryland-Delaware Association may become a member of the Federation without increase in membership dues. The subscription to *Sewage Works Journal* will be three dollars per year, but this is not required for membership in the local Association. Members voted unanimously to go on record as approving, in principle, joining the Federation under this plan. Authority was given to the executive committee to take appropriate action when further particulars become available.

C. A. Hechmer, Chairman of the Short School Committee, reported that forty-five of sixty registrants at the 1940 school were awarded certificates. The next school will be held in 1942.

Past President
G. E. Harrington, Chemist, Water Division, Washington, D. C.

New President
J. M. Jester, Chemist, Washington Sub. Sanitary Dist., Hyattsville, Md.

New Officers

The following officers were elected to serve for the 1941-1942 term:

President: J. M. Jester, Chemist, Washington Suburban Sanitary District, Hyattsville, Md.

First Vice-President: R. A. Norris, Sykesville, Md.

Second Vice-President: R. J. Stewart, Edgewood, Md.

Secretary-Treasurer: C. J. Lauter, Dalecarlia Filtration Plant, Washington, D. C.

Member of Executive Committee: J. W. Engle, Washington, D. C.

On the evening of the first day of the conference, the banquet was followed by sound films in color, "A New World Through Chemistry," produced by E. I. du Pont de Nemours and Co., and formerly shown at the New York World's Fair.

Transportation was arranged for informal inspection trips to three nearby plants. These were: Anacostia River Sewage Treatment Works, Bladensburg, Md.; District of Columbia Sewage Treatment Works, Blue Plains, D. C.; and the Robert B. Morse Filtration Plant, Burnt Mills, Md.

A ladies committee, consisting of Mrs. G. E. Harrington, Mrs. C. J. Lauter, and Mrs. R. C. Clement, provided a luncheon for members' wives. Trips to the new Art Museum and to a fashion show were also on their program.

Replacing the "Question Box" period announced on the regular program, was an illustrated talk on protective lighting: "Light Versus the Saboteur." This paper, presented by A. F. Lowe, General Electric Company, was in substance that which appeared in detail in WATER WORKS AND SEWERAGE in April, 1941, under the title "Protection of Water and Sewage Plants by Effective Lighting." It was advised that such lighting should be planned by experienced engineers and that consultation would be freely furnished by the General Electric Company representatives or by those of local power companies.

Technical Papers

"Treatment and Sterilization of Air-Conditioning Water Supply," by Harry Stevens, Sanitary Engineer, Washington, D. C.

Mr. Stevens told the story of an unusual problem in water pollution and of its economical solution. The Tidal Basin, known to all Washington visitors, was created to maintain the Potomac River in a sanitary condition. Twice each day it fills and empties an average depth of 1.5 feet. In 1938 the Basin was selected as the most convenient source of cooling water needed for air conditioning equipment provided in six federal buildings on Constitution Avenue.

These buildings have a total refrigerating capacity of 8,275 tons and require some 25,000 gallons of cooling water per minute. During the months of May 1st to October 1st this water is supplied from and returned to the Tidal Basin. When the refrigerating plants were started, it was found that organic matter

*Research Chemist, The Chlorine Institute, Inc.

clogged the suction strainers and coated condenser tubes to such an extent that endless shut downs, cleaning of strainers, and use of much valuable water from the city mains necessitated a solution of this problem. The organic growth was identified as consisting largely of Pectinatella (a type of fresh-water sponge) which accumulated in gelatinous masses, often equal to half a watermelon in size.

It was believed that water from the Tidal Basin could be passed through traveling screens for treatment, and Congress appropriated $36,000 for such equipment. Mr. Stevens, however, when called upon to prepare the design for this installation, decided that the organisms developed within the pipe lines in the dark, and that there were no accumulations which could be screened from the intake. Upon his recommendation, chlorination of the cooling water was tried as a means of controlling the growth.

Programmers
John W. Krasauskas, Bacteriologist, and
L. E. McClung, Engineer, Dalecarlia Filtration Plant, Washington, D. C.
Albert L. Genter, Consulting Engineer, Baltimore, Md.

A temporary chlorinating plant was provided on a rental basis by Wallace and Tiernan and treatment was started in May, 1939. Success of this treatment is best indicated by the figures quoted. In 1938, strainers in one of the buildings required cleaning 547 times; in 1939, after treatment was begun, only 2 cleanings were required. In 1940 permanent chlorinating equipment was installed.

Experience has shown that application of chlorine for 30 minutes out of each 4 hours of pumping will control organic growth. The dose is regulated by refrigerating requirements and treatment extends from 6 a. m. to 6 p. m.

About 2.0 p.p.m. chlorine is applied, to provide the desired residual of 0.5 p.p.m., but since the total time of treatment is only two hours per day the chlorine required costs only one dollar. An attendant visits the plant in the morning and again at night. Total completed cost of the plant was slightly over $20,000. Studies with various metals have shown that the concentration of chlorine used has no effect on any of the equipment.

Three Maryland Smiles
Mrs. R. C. Wilson, Hagerstown
Mrs. R. H. Morgan, Belair
Miss E. V. Gipe, Sec'y to Chief Eng'r, State Dept. Health, Baltimore, Md. (Ass't Sec'y of the Association since its beginning.)

Savings include cleaning of screens at a cost of $3,350 for six months; eliminated also is much of the cost of condenser cleaning and repairs. Together these savings, with increased condenser efficiency (removal of insulating slime) are credited with reductions in operating cost estimated to return the cost of the chlorinating installation in one year.

In subsequent discussion of this paper, *Mr. Hilquist,* Wallace and Tiernan Co., described how the many applications of intermittent chlorination for treatment of condenser cooling water have proven the economic advantages of such treatment. Some 20 billion gallons of water are so treated daily, intermittently, applying chlorine and, thereby, actually treating only one-tenth to one-twentieth of the total pumped.

What precautions should be provided against chlorine leaks when using ton containers was asked by *J. M. Jester.* In reply, *H. A. Faber,* Research Chemist, The Chlorine Institute, said the safety record of such containers was very high. The characteristics and inspection of this equipment is rigidly specified by regulations and the few transportation accidents involving containers have proved they can sustain damage without developing leaks. Only four cases are on record in which ton containers have developed leaks at water or sewage plants since they have first been available in 1917. Education of operators is the best protection against such difficulties ever arising, and in case of serious leaks the chlorine producers are glad to give prompt assistance if reached by telephone or telegraph.

"The New Anacostia River Sewage Treatment Works," by Harry R. Hall, Chief Engineer, and Herman Kratz, Superintendent, Washington Suburban Sanitary District, Hyattsville, Md.

Two-thirds of the Anacostia River District, with a population of 65,000, is served by this plant having a capacity of 7.5 m.g.d. Although an activated sludge plant was planned, the limited construction time available, approach of winter weather, and uncertain labor conditions all penalized the bids received. Estimated cost was $700,000 and the lowest bid was $1,259,000. Hence the commission decided to build the present plant which consists of primary sedimentation, aero-chlorination of the crude sewage for grease separation and odor control, sludge digestion, sludge elutriation and vacuum filtration, and effluent chlorination, with provision for ultimate adoption of activated sludge treatment.

The plant was completed in eight months at a total cost of $796,500 of which about $338,000 was supplied by PWA. It has now been in operation for five months, since November, 1940. As the site is on a flood plain, dykes are provided as protection. Excellent removals of B.O.D. (Raw 155, Effluent 70) and of suspended solids (Raw 130, Effluent 45) are accomplished by the treatment provided.

T. B. Nicol, Deputy Chief Engr. Metropolitan Water and Sewage Board, Sydney, Australia
(A visitor from afar.)
George L. Hall, Chief Engineer, Maryland State Dept. of Health.
John Geyer, Associate Professor, Dept. of Sanitary Engineering, Johns Hopkins University.

Several of the unusual provisions in the Anacostia plant were discussed by *Ralph E. Furman,* Assistant Supt., D. C. Sewage Treatment Plant, who praised the tunnels which connect all buildings and carry piping in accessible manner. (With the exception of gas lines which are outside so as to prevent pockets.) Commendable was the good operation resulting in production of digester gas in only a few weeks—during winter months. Regular sampling of the Anacostia and Potomac Rivers already shows improvement due to operation of this plant.

A. L. Genter, Cons. Engr., Baltimore, commented on the difficulty of explaining discrepancy between engineering estimates and bids of contractors. He cited a recent plant of the activated sludge type at Cranston, R. I. (having about the same population) for which bids were close to the $700,000 as was originally estimated for the Anacostia plant. The

fine architectural and utilitarian appearance of the new plant was especially praiseworthy.

G. E. Hall, Chief Engr., State Dept. Health, Baltimore, noted that activated sludge treatment will ultimately be required and sludge incineration may be provided.

"Laying Large Collecting Mains in an Operating Filtered Water Reservoir," by L. E. McClung, Dalecarlia Filtration Plant, Washington, D. C.

An unusual operation of laying mains in a covered filtered water reservoir while that reservoir was in use, and without pollution of the water, was described by Mr. McClung. The McMillan Filtration Plant in Washington is of the slow sand type, originally having no provision for chemical treatment. Twenty-nine filters discharge in combinations of 4, 10, 10, and 5 units through four separate mains into a clear water reservoir 160 x 600 feet in size.

T. W. Henderson, Ass't Engineer, Washington Suburban San. Distr., Hyattsville, Md.
R. C. Wilson, Sup't of Filtration, Hagerstown, Md.
R. L. Moore, Chief Engineer, Jessup, Md.

Because filtered water did not always meet the Public Health standards in winter and at periods of high raw water turbidity, the application of chlorine was started in 1922. This treatment was periodic until 1926, when chlorination became continuous. Gradual increase in the volume of water filtered and necessity for higher doses of chlorine resulted in taste complaints because chlorine could be readily applied at only one point, the 78 inch main carrying water from the reservoir to the distribution system.

In order to bring all the filtered water from four points of discharge to the north end of the reservoir, the reservoir was reconstructed in 1939, and a 12 inch brick baffle wall was built. This enabled chlorination of all water before it passed through the reservoir to the discharge end, and mixing of the water. As continuous use of the reservoir was necessary, the work was carried out by lowering the water level and uncovering 140 feet of the north end, while a depth of 13 feet in the south end provided storage for discharge to the 78 inch main.

Through a 6 x 10 foot opening in the roof of the reservoir it was possible to pass all construction material. Special sanitary precautions were taken to prevent contamination of the filtered water. A one per cent hypochlorite solution was prepared each day, and pipe, lumber, equipment of all sorts, as well as boats, and rafts were sprayed with this solution. Each shift had two inspectors, one devoting his attention solely to the sanitation of workmen and equipment.

Installation of the 36 inch and 48 inch steel pipe was largely from rafts, the pipe being floated into place by means of waterproofed canvas fastened over the ends. Concrete cradles were fastened to the pipe sections before lowering by cables and cables were released by divers. Slides were used to illustrate this work.

Despite the presence of workmen for 24 hours a day; the contamination which might be introduced by concrete work; and over 1,000 feet of pipe; so carefully was every item disinfected that the reservoir effluent met Public Health Standards at all times. Samples were taken every four hours for complete protection.

"Obsolescence of Filter Plant Equipment," by Edward S. Hopkins, Filtration Engineer, Bureau of Water Supply, Baltimore, Md.

Comparisons of equipment in an old water plant with that of a new plant is unfair, if the old plant equipment is functioning satisfactorily. Mr. Hopkins stated. But old equipment must be maintained in the best possible operating condition, and not viewed with contempt or a lax attitude.

Often the efficiency of a new machine may be so great as to pay for its cost; for example, the efficiency of pumps has generally increased from 65 per cent to 90 per cent, and this decrease in power requirements makes the retention of old equipment costly. Amortization was defined as original cost extended over a fixed period of years, plus the interest for that period. The period selected may be the useable life of the equipment, or the period before which it is rendered obsolete by more efficient models.

Standard equipment should be used as far as possible, and homemade parts resorted to only in emergencies. Frequent testing is essential to maintain efficiency; readiness to make repairs, and a knowledge of operating costs are essential to the prevention of premature obsolescence, in Mr. Hopkins' opinion.

R. J. Stewart, Edgewood Arsenal, Md., said that experience over a period of years gave the best practical meaning of obsolescence. He cited the use of two turbo-generators in his plant from 1918 to 1925, when they apparently became obsolete. The equipment was maintained, however, and now that emergency equipment is needed, approximately $50,000 is being saved by its reconditioning. Wood tub filters have been in operation at his plant since 1918 and after 23 years of use produce a finished water of only 0.3 p.p.m. average turbidity.

"Water Bacteriology and Chlorine Residuals," by John W. Krasauskas, Bacteriologist, Dalecarlia Filtration Plant, Washington, D. C.

While a low typhoid death rate has resulted from purification of water and from the efforts of State Health Departments in the elimination of carriers, Mr. Krasauskas warned that operators should fight a false

John M. Diven, District Mgr., The Leadite Co., N. Y. City
C. G. Webber, Sup't. of Sewage Treatment, Annapolis, Md.
Paul Lanham, Engineer, Div. of Water, Washington, D. C.

sense of security. The residual chlorine test should always be considered in relation to bacteriological tests and presumptive confirmation tests should be made, using Brilliant Green Bile medium.

Coliform organisms provide a good index of sanitary quality because they are always associated with typhoid, while only an aerogenes flora may be present with dysentery organisms. It is safer, he indicated, to chlorinate to the point of insuring absence of all coliform organisms than to count on differentiation of coli and aerogenes forms.

"Some Chlorination Observations —Mostly Unimportant"—by L. L. Hedgepeth, Manager, Technical Service Department, Pennsylvania Salt Manufacturing Company.

Mr. Hedgepeth stressed the fact that neither the ortho-tolidin nor potassium iodide-starch method of residual chlorine determination provided a measure of the germicidal efficiency of the chlorine dose applied to water. While an oxidation-potential method of measurement appears to

(1) Mrs. G. E. Harrington and Mrs. C. J. Lauter, Washington, D. C., of the Ladies' Entertainment Committee; (2) Mike Glace, Cons. Eng., Harrisburg, Pa., with Miss Glace, Mrs. Glace, and Frank Bachmann, The Dorr Company, New York; (3) Frank Kuska, Eng. Asst.; Doris Obersider, Chemist; Henry Schilpp, Asst. San. Eng.—all of State Dept. Health, Baltimore, Md.; (4) Edgar Donaldson, Eng., Annapolis, Md., and Mrs. Donaldson.

have real promise, this is not yet a very practical procedure and final proof of safety of finished water must depend upon bacteriological results.

The "Observations" which Mr. Hedgepeth made were non-technical but far from facetious. He noted that too little is still known of the actual chemical behavior of chlorine when added to water for chemical treatment. Water purification plant operation itself still remains more art than science, although control is, and should be, principally scientific.

There appears to be a growing belief amongst the public that too much "treatment" is being given to water and that there should be less, rather than more, complexity. Yet the quality improvement by modern methods under proper control is well justified when such treatment is needed. Application of alum and chlorine without proper control has resulted in public prejudice. Inefficiency of purification plant operation is often traceable to the public because of its indifference or unwillingness to maintain adequate treatment.

The medical profession frequently brings unfair and unfounded charges against the effect of chlorine in water supplies; for example, cancer has been ascribed to this cause. But doctors engaged in the field of public health work have a more constructive attitude, and the American Medical Association has defended the proper use of alum and chlorine in water treatment.

Less than seven per cent of the total tonnage of chlorine produced in the United States during peace times is devoted to water, sewage, and other sanitation uses. Because this is such a small proportion of total production, there is no indication of a shortage of this material for sanitary needs.

The papers by Mr. Hedgepeth and Mr. Krasauskas evoked considerable discussion. *H. A. Faber,* The Chlorine Institute, pointed out that the ortho-tolidin test could not show whether chlorine was present as free chlorine, as chlorine-ammonia chlorine, or as chloro-protein compounds. He agreed that final evidence of quality depended upon bacteriological tests but noted that both were essential for proper control. Ortho-tolidin still provides the most practical standard for regulating dosage until quality can be proven by the relatively long bacteriological tests.

A question by *Fred Stuart,* President, Activated Alum Corp., Baltimore, regarding the apparently greater chlorine demand indicated by the 20° C. count as compared to the 37° C. count was answered by *Mr. Krasauskas.* He explained that the organisms growing at 20° C. are of soil origin and are more resistant because many exist as spore forms. Chlorine treatment frequently stimulates the development of vegetative forms of such organisms which are more susceptible to disinfection.

Both *E. S. Hopkins* and *C. J. Lauter* pointed out that this was really a recommendation for both pre- and postchlorination, since both spore forms and vegetable forms could be destroyed.

I. M. Glace, Cons. Engr., Harrisburg, Pa., commented on the advance in modern conceptions of water quality. At the Allentown, Pa., plant it has been found that prechlorination to supply a residual of 0.8 p.p.m. has satisfied the demand of old organic accumulations within the filters, until now the effluent contains a residual closely approaching that of the applied water.

"The Principles of Vacuum Filtration of Sludge," by Albert L. Genter, Consulting Engineer, Baltimore, Md.

Mr. Genter presented a most comprehensive paper based upon his extensive background of experience in vacuum filtration, drawing attention in a practical manner to a variety of little-recognized factors in this method of treatment. He pointed out that dewatering begins upon the arrival of sewage at the plant.

Gravity does about 195 times more dewatering than is done by vacuum filters handling the sludge from plain sedimentation or digestion. It removes over 3,000 pounds of water per pound of suspended solids, and over 5,500 pounds of water per pound of settleable solids; which is 99.4 to 99.6 per cent of the entire job of dewatering. As the fraction of water to be removed becomes smaller, the expenditure of money per pound of water becomes greater.

In vacuum filtration, water is drawn through the solids with a force greater than gravity—as contrasted with gravity removal of solids, in which the solids are drawn down through the water. In such forced filtration, water will be drained from digested sludge about 2,000 times faster than will gravity (aided by evaporation) do the same work on a sand bed.

Mr. Genter listed eight factors which govern the flow of liquids through a filter, eleven more factors introduced by the construction of vacuum filters, and finally, thirteen factors specifically related to the filtration of sewage sludge.

To cite only one instance of these extensive observations, it was noted that filter cake sloughing is due to coarseness of sludge floc and to filtering upside down. Ferric chloride coagulation may produce such a coarse floc that excellent Buchner filter tests, but exceedingly poor vacuum filter results, are obtained. Paradoxical as it may seem, a thick and overly flocculated sludge is frequently detrimental to the operation of some filters. In a laboratory filter, the floc rests on a stationary medium and filtration is always downward; on the rotating drum of a vacuum filter, solids are deposited on a moving surface inverted in the sludge, hence a thick cake of sloppy floc will accumulate rapidly. This cake becomes so thick that much of it is dragged from the drum surface by the sludge both before it can become dry and compact. Such floc he termed as being "too good for the filter." The thicker it becomes, the worse its dragging and scouring action, and an uneven cake with frequent bare or thin spots is produced.

There are two cures for this condition: One, by dropping the level of sludge in the filter-vat when the type of filter permits this operation. Two, by vigorously beating the floc in the mixer in order to prevent a heavy cake accumulating on the drum. It is usually unnecessary to produce an excellent floc and then

(1)"Smoke" Clement, W. & T. Co., Washington, D. C., and "Mac" Bingley, Dorr Co., Richmond, Va.; (2) Bob Haywood, Supt. of Filtration, Chester, Pa., and Bill Eastburn, Mathieson Alkali Co., Philadelphia, Pa.; (3) F. S. Smith and P. W. Vogel, Ass't. San. Engineers, State Health Department, Baltimore, Md.; (4) L. C. MacMurray and M. H. Coblentz, Engineers, State Health Dept., Baltimore.

deliberately destroy it, because filter construction does not permit the dewatering of a well-flocculated sludge.

Mr. Genter stressed the advantage of laboratory testing methods for guidance in plant operation, and his common-sense observations warrant wide publicity.

Instead of discussing this extensive paper, *P. D. McNamee,* Chief Chemist, D. C. Sewage Treatment Plant, described successful cleaning of blinded filter cloth using oxalic acid treatment suggested by Mr. Genter. He also mentioned the possibility of recovering ferric coagulant from ferrous iron in the filtrate, pointing out that this might be some economical if ferric chloride becomes higher in price.

"Successful Planning of Sewage Treatment Works," by Robert T. Regester, Consulting Engineer, Baltimore, Md.

The planning of a sewage treatment works, to be successful, must be a progressive art—and depends upon all those connected with the plant. Mr. Regester's remarks were based upon the designs of nine plants with which he has been associated.

First to be considered, is the degree of treatment required: Whether or not proprietary processes are involved must be recognized. The activated sludge type of treatment exceeds in application all other proprietary processes. By means of slides, Mr. Regester illustrated how area and topography must be appropriate if the cost is to be moderate.

As an example, the Columbus, Ohio, plant is an ideal site since a gentle slope provides the advantages of hydraulic flow.

Most important in sanitary design is the flow sheet which shows minimum and maximum flows and detention periods, as well as the degree of purification at each station. Structural and architectural features are rather uniform in the U. S., generally being functional and economical in addition to being aesthetic.

A description of the Baltimore activated sludge plant, with comparisons to the original trickling filter plant, portrayed the greater accomplishment in a lesser area. Thought must be given to possible future enlargement together with economy and flexibility of construction.

Symmetrical design permits centralization of all operation in a conveniently located building. The Anacostia River Plant was designed to suit the site available and illustrates many of the points described.

Mr. Regester mentioned many basic factors but concluded that, eventually, the success of the plant depends upon its operator. When the plant has been constructed, the results obtained are due to the resource, the energy, the mechanical and managerial abilities of the operator; best of all is that operator who has a research type of mind, and can make what he has available do the job.

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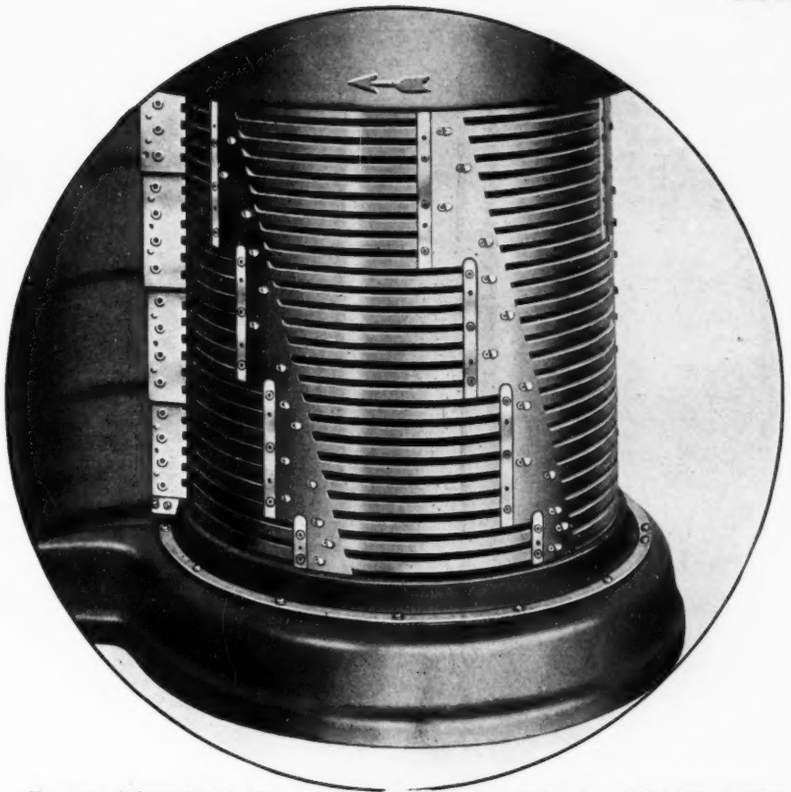

Close-up of Comminutor drum, showing distribution of cutters for minimizing shearing stresses and power requirements.

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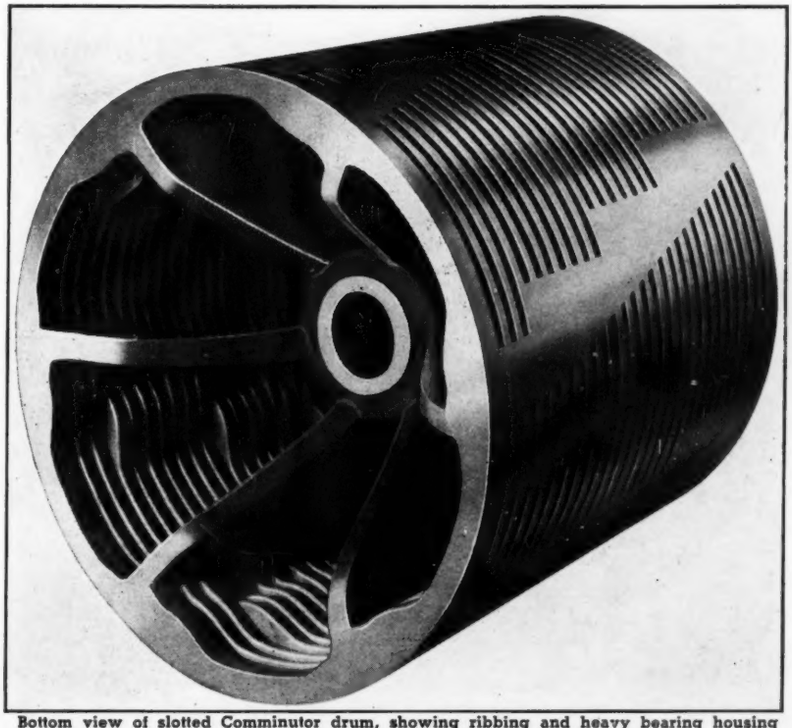

Bottom view of slotted Comminutor drum, showing ribbing and heavy bearing housing necessary for maximum rigidity and strength.

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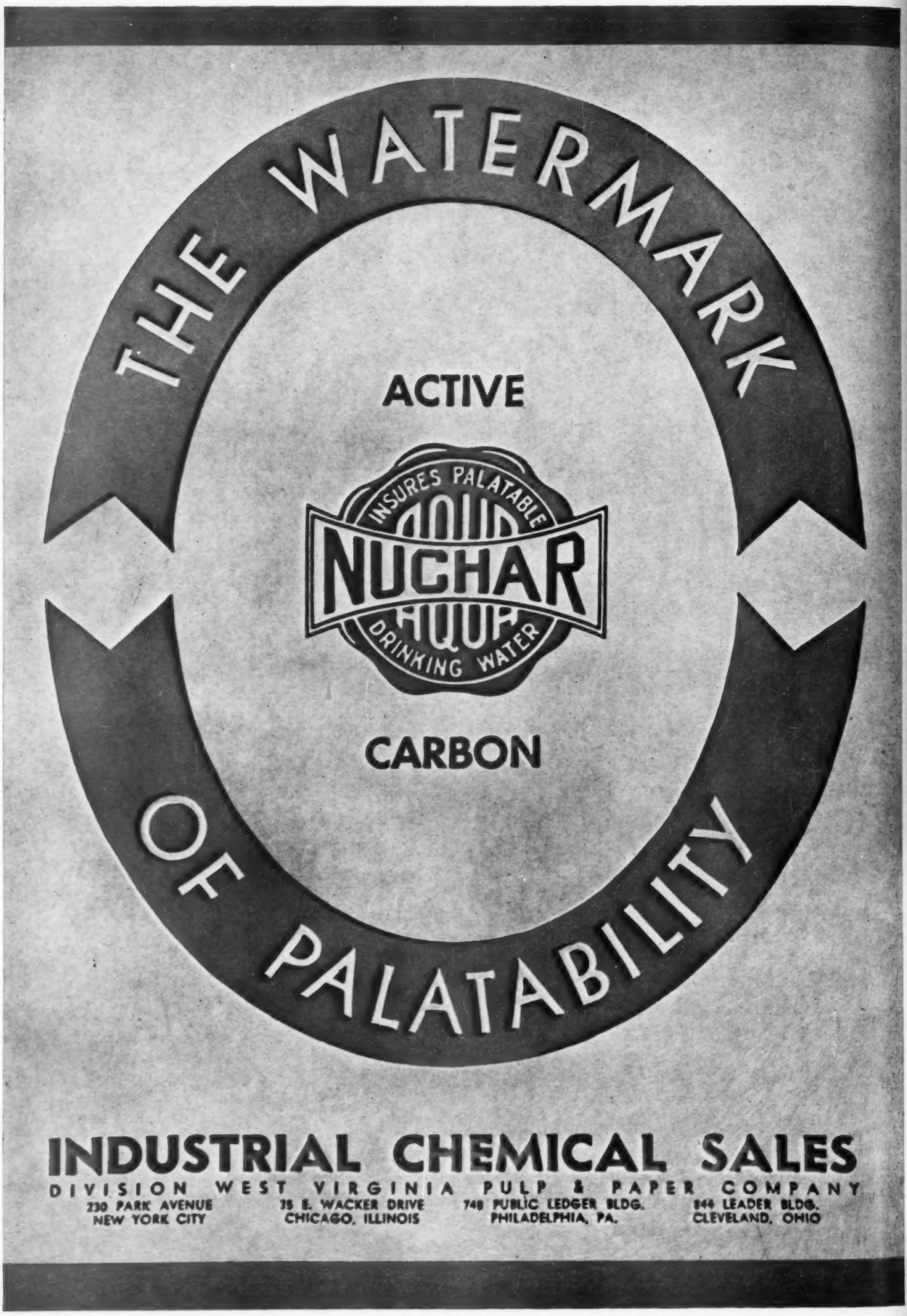
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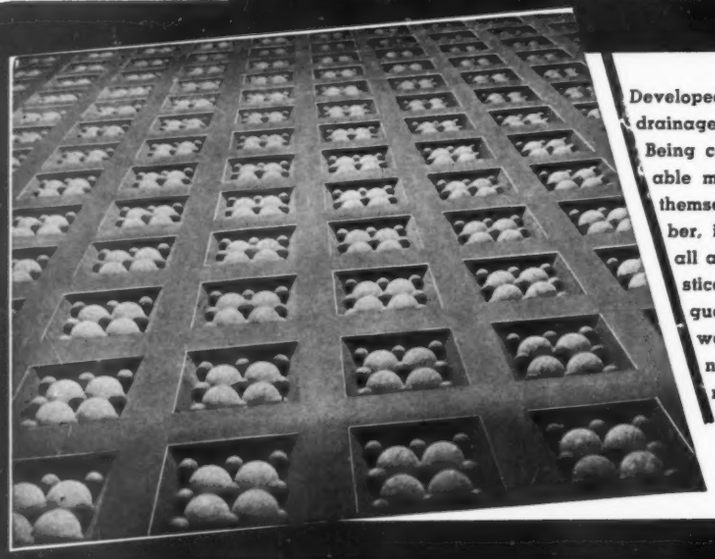

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Alabama Ordnance Wks., E. I. du Pont de Nemours & Co., Inc., Childersburg, Ala.	20,000,000
Champion Paper & Fibre Co., Canton, N. C.	10,000,000
City of Sandusky, Ohio	9,000,000
City of Charlotte, N. C.	8,000,000
City of Raleigh, N. C.	8,000,000
Southern Bleachery & Print Wks., Taylors, S. C.	7,500,000
City of Rocky Mount, N. C.	6,750,000
City of Hamilton, Ohio	6,000,000
City of Gloversville, N. Y.	6,000,000
City of Greensboro, N. C.	6,000,000

	GPD
Ducilo S. A. Productora de Rayon, Buenos Aires, Argentina	4,500,000
Lanett Bleachery & Dye Wks., Lanett, Ala.	4,500,000
Aluminum Co. of Canada, Ltd., Arvida, Quebec	4,000,000
Fort Bragg, N. C.	4,000,000
Proximity Mfg. Co., Greensboro, N. C.	3,500,000
Proximity Mfg. Co., Greensboro, N. C.	3,000,000
City of Wilson, N. C.	3,000,000
Rosemary Mfg. Co., Roanoke Rapids, N. C.	2,250,000
City of Fayetteville, N. C.	2,000,000
Canadian Industries, Ltd., Beloeil, Quebec	2,000,000
City of Aguadilla, Puerto Rico	2,000,000
Borough of Media, Pa.	2,000,000
Reynolds Metals Co., Lister, Ala.	1,875,000
City of Tarboro, N. C.	1,500,000
City of Hickory, N. C.	1,500,000

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E. I. du Pont de Nemours & Co., Inc., Belle, W. Va.	1,500,000
Morgantown Ordnance Wks., E. I. Du Pont de Nemours & Co., Inc., Morgantown, W. Va.	1,500,000
E. I. Du Pont de Nemours & Co., Inc., Martinsville, Va.	1,440,000
Town of Rockingham, N. C.	1,000,000
Town of Albemarle, N. C.	1,000,000
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City of Humacao, Puerto Rico	1,000,000
Duke Power Co., Spindale Water Wks., Spindale, N. C.	1,000,000
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THE SEWAGE TREATMENT PLANT OF FORT SLOCUM

By PHILIP ARTESE
Operating Engineer,
Sewage Treatment Plant
FORT SLOCUM, N. Y.

FORT SLOCUM is located on David's Island in Long Island Sound, opposite New Rochelle, N. Y.

The Post's sewage treatment plant, designed by the Construction Quartermaster, Washington, D. C., is operated under the supervision of the Post Quartermaster.

Fort Slocum's sewer system is a separate sanitary type, the only industrial waste being from the Post laundry. Sewage entering the treatment plant is of average strength. Plant capacity will accommodate a flow of 500,000 gallons per day. The present connected population load is 2,100 average for the day, but being an embarkation post, the population varies from day to day.

Treatment involves pumping of raw sewage, basket screens, grit chamber, sedimentation tanks, pumping of sludge, separate sludge digesting tanks, chlorine equipment and glass covered sludge drying beds.

All sewage flows by gravity to Sumps A, B, and C, which are located in different sections on the Post. From sumps, sewage is then pumped to disposal plant. There is a basket screen at each sump through which the sewage flows before reaching the pump suction. The basket is hoisted and manually cleaned every two weeks and screenings are buried. Sewage enters grit chamber through two channels, 2 by 4 by 6 feet. In this way one channel can be in operation while the other is being cleaned.

The Author

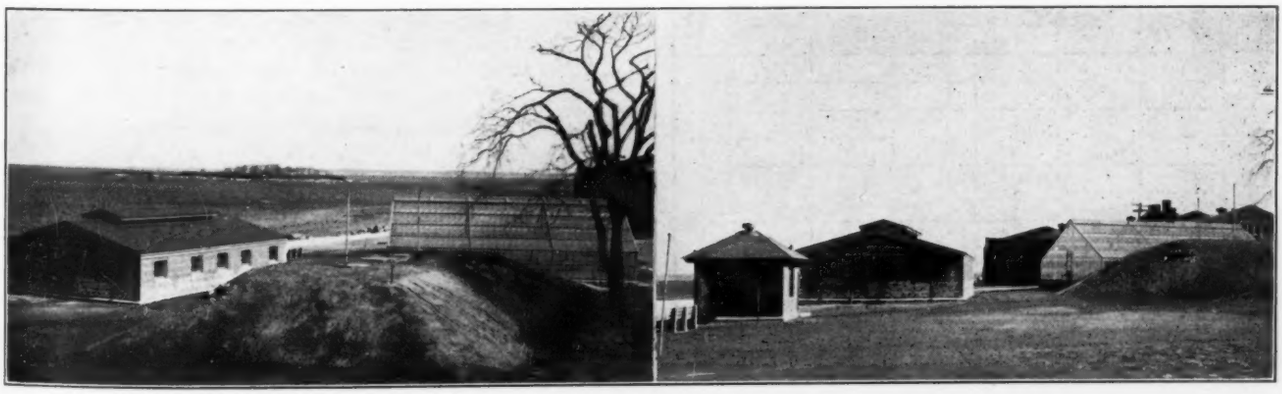
From grit chamber, sewage flows to sedimentation tanks which have hopper bottoms. At present two tanks are in operation, providing a detention period of one and one-half hours. Sludge is taken from bottom of sedimentation tanks by sludge pump and pumped into digestion tank.

And the Boys Catch Fish Off of Our Effluent Discharge Line Into the Sound.

There are two unheated, covered, separate sludge digesters with hopper bottoms, total capacity of 60,000 gallons. The sludge pump is also used to recirculate sludge in digesters. The tanks are provided with supernatant liquor draw-off at three levels. Lime is added to the digesters by feeding a slurry to the top of tanks, while pumping, to keep the reaction neutral or a little above. Sludge is pumped to glass covered sludge drying beds which have a total area of 2,000 sq. ft. Dried sludge is used on the Post grounds as fertilizer.

Chlorination equipment includes one W. & T. Semi-Automatic machine, which is used for pre-chlorination but can also be used to post-chlorinate. Raw sewage is chlorinated at the grit chamber only from May 15 to Sept. 15 of each year. A residual of 0.5 is carried through plant during this period and the final effluent is discharged into Long Island Sound.

There are weekly inspections by the Post Quartermaster, Army Medical Officer, and periodic inspections by a representative of the New York State Board of Health. The plant complies with rules and regulations set by the State Board of Health and the Tri-state Sanitation Commission.



Two Views of Fort Slocum's Treatment Plant on the Edge of Long Island Sound.

OPERATING FUNDAMENTALS OF THE ACTIVATED SLUDGE PROCESS

T. R. HASELTINE
Supt. Sewage Treatment
BUTLER & GROVE CITY, PA.

THE properties of activated sludge which are most important to the plant operator are, first, its clarifying or adsorptive powers and, second, its oxidizing power.

When activated sludge is mixed with sewage it absorbs the finely divided suspended matter, the colloids, and probably much material in true solution, in or on its floc surfaces. If the sludge is then allowed to settle out the supernatant liquor will be clear instead of cloudy. This clarification action is very rapid and is probably completed in 10 to 30 minutes.

The Author

The oxidizing power of activated sludge is generally assumed to be entirely due to biological action. Although its oxidizing action may be some 60 to 130 times faster than the normal oxidizing rates, as measured by the standard B.O.D. test, it is still much slower than adsorption or clarification.[1] The highest rate of oxidation usually occurs when the sludge first comes in contact with the sewage. It then falls off gradually for the next two to five hours after which it continues at a more or less uniform rate for considerable periods of time.

In any properly functioning plant there is a balance between these two properties. Almost all of the troubles encountered with the activated sludge process may be traced to a lack of proper balance. For example, if biological oxidation proceeds more rapidly than adsorption the sludge floc become very small and compact. This dense floc does not produce a sparkling clear effluent although nitrification may be very high. Furthermore, some of the floc are apparently broken up into minute particles which do not settle in the final clarifiers, even though the main body of the sludge settles very rapidly. On the other hand, if oxidation lags behind adsorption the sludge floc will become so light that it will not settle in the final tanks and the sludge will lose much of its clarifying power. Since adsorption is very rapid and almost automatic the operator's problem is to regulate the rate of biological oxidation so that it just keeps pace with adsorption under the aeration periods prevailing in his particular plant.

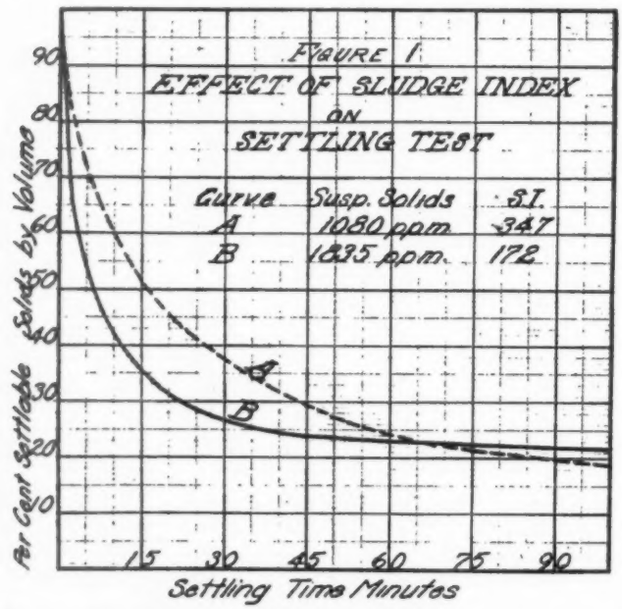


Fig. 1.—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

There are several conditions under which oxidation will progress more rapidly than adsorption. Probably the most common is over aeration. It is encountered in plants having excessive blower capacity in a few large constant speed machines. It is best overcome by carrying more sludge in the aeration tanks. A second, but less common, cause of over oxidation is too long an aeration period. The best corrective is to bypass part of the aeration tanks. If that can not be done, then increase the amount of sludge in the mixed liquor. A third cause of over oxidation may be lack of sufficient "food" in the sewage. The writer encounters such a condition at Grove City during the early spring. At such times our sewage flow is increased by ground water to four or five times its dry weather volume. Most of the excess flow has to be bypassed and hence only ⅓ to ¼ as much organic matter enters the aerators as normally. We have found that the admittance (after liming) of digester supernatant to the aerators was quite helpful at that season.

Causes of Oxidation Lag

There are at least six possible causes of oxidation lagging behind adsorption, as follows:

(1) *Inadequate Oxygen Supply:* In any aeration tank (mechanical or diffused air) we have two opposing forces, one, the aerator device injecting air into the mixed liquor, and two, the biological organisms using up oxygen in their life processes. Dissolved oxygen determinations on the mixed liquor give a measure of the excess of the oxygen supply over the oxygen consumption. It is absolutely essential that the rate of supply be at least equal to the rate of consumption, but there is nothing to indicate that any great excess is beneficial.[2] If there is no dissolved oxygen in parts of the aeration tanks then either the oxygen supply must be increased by using more air, or the rate of oxygen consumption must be cut down by reducing the amount of sludge or sewage in the mixed liquor. Naturally sludge reduction is the most general practice.

(2) *Germicidal Wastes:* Since oxidation is entirely biological it is evident that germicidal wastes will stop or retard it. If the germicidal action is due to excessive acidity or alkalinity neutralization with lime or acid will eliminate it. (The optimum pH for biological oxidation is 7.0 to 7.5 although there is little retardation at pH 6.4 to 8.0.[4] If it is due to phenolic compounds or other toxic substances, the only certain remedy is to exclude them from the sewers. In some cases, however, where the concentration of the poison is quite uniform and not too high it may be possible for the sludge organisms to become accustomed to it.

(3) *Excessive Carbon Dioxide:* Carbon dioxide is one of the principal end products of biological oxidation [3 4] and excessive amounts of it are known to be toxic to bacterial activity. Sewage already contains relatively large amounts of CO_2. Although aeration is an efficient means of removing carbon dioxide the rate of its production during the activated sludge process is so great that the net reduction due to aeration may be slight. In such cases it is quite possible that the rate of oxidation is limited by the CO_2 content of the mixed liquor. When such conditions prevail it is logical to apply lime to the inlets of the aeration tanks.[4] Either one of two general schemes may be followed; (a) daily applications of 50 to 300 lbs. of lime per M.G. of daily flow applied in one to four "shots" during hours of peak sewage flow, or (b) continuous lime applications at rates of 300 to 500 p.p.m. until such time as the pH at the outlet of the aerators approaches 8.0. The best way to tell whether or not excessive CO_2 is causing trouble is to try the lime treatment. It is fortunate that this treatment can do no harm so long as the pH at the outlet of the aerators does not exceed 8.8, whether or not it does any good.

(4) *Septic Sewage or Sludge:* Septic action not only increases the carbon dioxide but produces other products that retard biological oxidation. Avoid sludge accumulations in sewers, channels, primary or final clarifiers. The return of large volumes of poor quality digester overflow liquor to primary tanks may cause the entire sewage flow to become septic. Frequent sewer flushing may be helpful. Prechlorination at various points along the collection system may be even more helpful. Partial chlorination of the return activated sludge has proved beneficial at some plants but chlorine is a powerful germicide and particular care is required to avoid overchlorination of the sludge which might destroy its oxidizing power.

(5) *Excessive Grease Content of the Sludge:* If the grease content of the sludge is excessive the sludge particles become coated with a film of grease thus preventing intimate contact with oxygen, even though tests show an abundance of dissolved oxygen in the mixed liquor, hence oxidation is greatly retarded. Wiest's [6] work indicates that the activated sludge process functions satisfactorily when the grease content of the sludge is 5 to 7% but gives considerable trouble when the grease content is around 20%. The writer's experience indicates that 13% grease in the sludge makes for difficult operation while 30% grease causes the sludge to lose its clarifying power and a very inferior effluent results. If the grease content of the sludge is generally excessive then some means of further removing grease from the incoming sewage is indicated. But where the trouble is caused only by periodic shots of mineral oil the writer has found a 25% increase in air for a day following such shots to be helpful.

(6) *Inadequate Aeration Period:* Even under ideal conditions biological oxidation is much slower than adsorption and, hence, there is some minimum aeration period required below which the process will not function. Usually there is nothing the operator can do but bypass part of the sewage flow and ask for more aeration tanks. In some cases, however, short circuiting in diffused air plants has been a factor that could be corrected by proper baffling. Current meter readings at various points may be helpful in designing or locating baffles. In other cases it has been possible to delay major extensions by utilizing part of the aeration tanks for sludge reaeration, thus lengthening the available time for biological oxidation.

Since both the quantity and strength of the sewage varies from hour to hour and day to day, it might be asked, how is the operator to maintain a constant balance between adsorption and oxidation at all times. He can not! In the normal plant oxidation probably falls behind adsorption during the high flow of strong, daytime, sewage and catches up during the low flow of weaker night sewage. In some plants it is even possible to observe a gradual deterioration of the sludge through the week with recovery over Sundays. It must always be kept in mind that it is only prolonged periods of excessive adsorption that cause serious sludge deterioration, and that several days of excessive oxidation are required for its recovery. The closer the balance is maintained the lower will be the power costs, but the higher will be the laboratory and attendance costs. Therefore more laboratory work is justified in large plants than in small, but some is required in all.

Sewage Input vs. Air Input, and the D. O. Test

Since most if not all of the oxidation occurs in, or on, the sludge floc it should be evident that most of the oxygen is consumed by the sludge. Therefore, it is a serious mistake to attempt to regulate the air input in proportion to the sewage flow. Dissolved oxygen determinations throughout the aeration tanks are the best criterion known for air regulation. If the air is to be varied throughout the day then these tests should

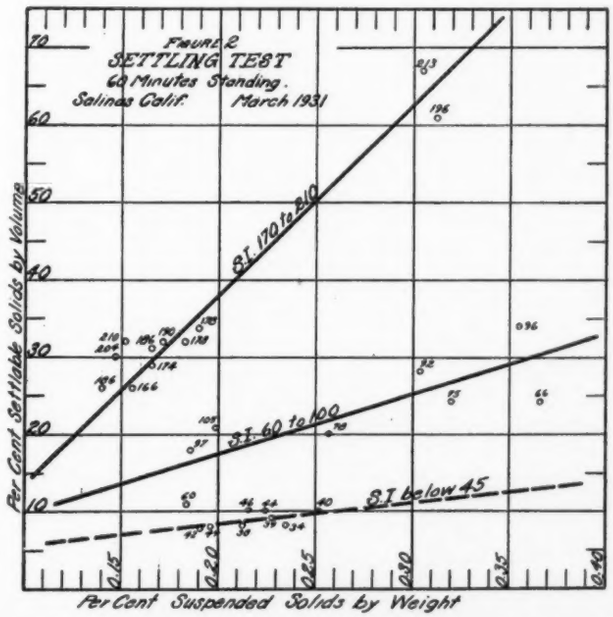


Fig. 2.—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

be made at various hours throughout the day. If a constant rate of aeration is to be used then the tests should be made at whatever time the dissolved oxygen is at a minimum; this will usually be found a few hours *after* receipt of the peak sewage flow. Samples should be collected from various points between the inlet and the outlet of the aerators. Unfortunately the dissolved oxygen determination, the most important of all operating control tests, can not be made directly on the mixed liquor because of interference from the sludge floc. The accurate determination is extremely difficult and requires special equipment,[7] however tests for routine plant control may be made on samples of supernatant liquor siphoned off from larger samples of mixed liquor collected from the aerators. At Salinas, California,[5] the writer collected 2 liter samples from the tanks and allowed them to stand until sufficient clear water could be siphoned off to fill the small D.O. bottles. Ordinarily 5 to 15 minutes standing sufficed although at times of severe bulking as much as 40 minutes was required. That procedure is open to the objection that the sludge consumes some oxygen during the sedimentation period. However, on several occasions we siphoned off a second sample an hour or two after taking the first one and repeated the D.O. determinations; the decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small. Theroux, Eldridge and Mallman[8] recommended the addition of 10 ml. of 10 per cent copper sulphate solution to the 2 liter samples of mixed liquor. The copper sulfate acts as a coagulant, speeding up sedimentation, and at the same time halts biological oxygen consumption. Theoretically, at least, this method is open to the objection that the copper sulfate tends to react with the potassium iodide added later liberating iodine and thus giving results that are too high. Heukelekian uses about half as much 10 per cent sulfuric acid in place of the copper sulfate. The writer has tried all three methods simultaneously at Grove City on several occasions and found little or no practical difference. We use copper sulfate in our routine work.

Regardless of the method used to separate out the sludge floc the Rideal-Stewart modification of the Winkler method should always be used for determining the oxygen in the small, siphoned samples because of the possible presence of nitrites in the liquor, see "Standard Methods."[25]

Measuring Sludge in Mixed Liquor

We have mentioned increasing or decreasing the amount of sludge in the aerators as a means of controlling the oxydation-adsorption balance. This leads us to the second most important control test, namely, some means of measuring the amount of sludge in the mixed liquor. By amount of sludge we mean *weight* of sludge solids. No universal rule can be given for determining the proper amount. Perhaps 600 to 1500 ppm. of suspended solids in the mixed liquor would cover most mechanical aerators while 1200 to 3000 would cover most compressed air plants. The higher the sludge content of the mixed liquor the faster will adsorption and oxidation progress, but the greater will be the power requirements. If the aeration period is short an increased sludge content will give a higher degree of treatment, but if an adequate aeration period is available almost as good purification can be obtained with a low sludge content and a considerable saving in power may be realized. With a low sludge content organic matter adsorption per unit weight of sludge is very high and hence a very high rate of biological oxidation must be maintained. Therefore, if the sludge content is low, there is more danger of a plant being upset by sudden shots of strong sewage or organic trade wastes.

Standard suspended solids determinations are the only accurate means of finding the actual weight of sludge solids in the mixed liquor. Unfortunately the test requires considerable time and, for small plants, expensive equipment. In spite of these handicaps the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day. The time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day—usually 8 or 9 a. m. will be the most satisfactory time. The writer has followed this practice at Salinas[5], Topeka[16] and Grove City. We governed the daily amount of activated sludge wasted almost entirely by the results of these determinations. This procedure does *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably a minimum at the time the peak flow started coming in and at a maximum in the evening when the sewage flow drops off. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant. If it is desired to hold the solid content of the aerators constant throughout the day then one of the approximate "short-cut" methods of solid determination, (to be described later) may be used as frequently as desired, but the standard suspended solids test should be made daily as a check on the short-cut procedure. After considerable experimentation the writer has concluded that the saving in power made possible by hourly checks of the solid content of the aerators was not sufficient to justify the time consumed in checking, but such a conclusion can apply only to the plants with which he was connected. Anderson, employing a centrifugal estimation, has found the opposite to be the case at Rockville Center.[11, 12, 13]

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas[5] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 ppm. under varying sludge conditions; at Grove City the range is 200 to 500 ppm.

Because of the time required for suspended solids determinations various short-cuts have been used. The simplest are the settling tests and these were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of that time. In the early days it was usually customary to carry a volume of about 20 per cent sludge, after 30 minute standing of the mixed liquor. The test is still used and is quite helpful so long as its limitations are kept in mind. Various standing times are used, ranging from 10 minutes to 1 hour or even longer.

The Sludge Index

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of suspended solids in the sample soon showed that no such relationship existed unless the sludge index[9] was also taken into consideration, see Figure 2. "The

sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes;" it is computed by multiplying the per cent sludge by volume after 30 minutes standing by 10,000 and dividing that product by the parts per million of suspended solids by weight in the same or a similar sample of mixed liquor. The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and, hence, the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. In general the settling test alone can not be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate determinations.

The Centrifuge Test

Another short-cut is the centrifugal test. This test consists of collecting samples of mixed liquor or sludge in 15 ml. centrifuge tubes and "spinning" them for a given short time (2 to 10 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed.

The writer first heard of this test being used at the Indianapolis plant in 1928. Like the settling test, it is, at best, a volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. First, it is extremely rapid, and second, it compacts the solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. The writer has used a 2 minutes spinning period at 2600 f.p.m. at Salinas and Grove City. At both plants we found that the results of this test were greatly influenced by the sludge index, see Figure 3. Setter[10] used a 10 minute period at the same speed and got fair correlation with the suspended solids test so long as the suspended solids exceeded 1000 ppm.; at lower solids concentrations the volume of sediment was too small to permit satisfactory readings. Anderson[13, 11, 12] used a 5 minute period at 1800 r.p.m. at Rockville Center and considers the test very satisfactory although he gives no data to correlate it with suspended solids determinations. If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index at daily to weekly periods and from that determination and the graph he can select the desirable centrifugal test results for more frequent determinations.

In addition to determining the amount of sludge being carried in the aerators it is desirable to know something of its condition. The sludge index, as previously described, is valuable in this respect. Color, odor, and floc structure are also valuable. Periodic microscopical examinations are useful. After a little experience these tests, or observations, will usually be found adequate for most plants. In some cases the volatile content or dissolved solids content of the sludge may be found helpful.[5] Still better tests require special equipment such as the Odeeometer[14], Oxy-Utiometer,[15] etc.

Tapered Aeration vs. Delayed Loadings

It was previously stated that the rate of oxidation was usually highest when the sludge first comes in contact with the sewage and that afterwards it falls off gradually. If the air is supplied in just sufficient amounts to maintain a minimum dissolved oxygen content at all points in the tanks it will be found that considerably more air is used at their inlet ends than is used at their outlets. This method is known as *tapered aeration.* Since the rates of adsorption and oxidation increase with increased amounts of sludge, tapered aeration is more necessary when a high sludge content is carried. The rates of oxygenation is limited for any areation device, but is generally lower for mechanical aerators than for compressed air plants,[17] hence the former usually carry less sludge and frequently provide longer aeration periods. At the new Tallman's Island[18] plant provision is made for adding sewage or return sludge at several different points along the aeration tanks, thereby avoiding the necessity of using such high aeration rates at their inlets. In small plants it is possible to reduce the necessity for tapered aeration by returning a large volume of very dilute sludge. Experience has taught many operators that this practice is a good one for small plants in particular. The excess water reduces the oxygen demand of the mixed liquor at the aerator inlets and forces the sludge along the aeration tanks faster, thereby reducing the air requirements at the inlet end and increasing it further along the tanks.

Importance of Prompt Sludge Recirculation

It used to be considered good practice to carry a considerable depth of sludge in the final clarifiers in order to get as high a solid content, and hence as low a volume of, return sludge as possible. Studies[19] have shown that the oxygen demand of such sludge is frequently so high that it is almost impossible to satisfy it by any aerating device. It has also been found[20] that the activity of the sludge was greatly impaired by even comparatively short concentration periods in the clarifiers and that the fresher the sludge the greater was its purifying power; the effect being most noticeable at plants having a short aeration period. Therefore, the rate of withdrawal from final tanks should be such as to remove the sludge as quickly as possible. In large plants where the cost of pumping excess water may exceed attendance, or in plants using sludge reaeration, it is wise to make frequent sludge soundings and to keep the rate of withdrawal at a minimum consistent

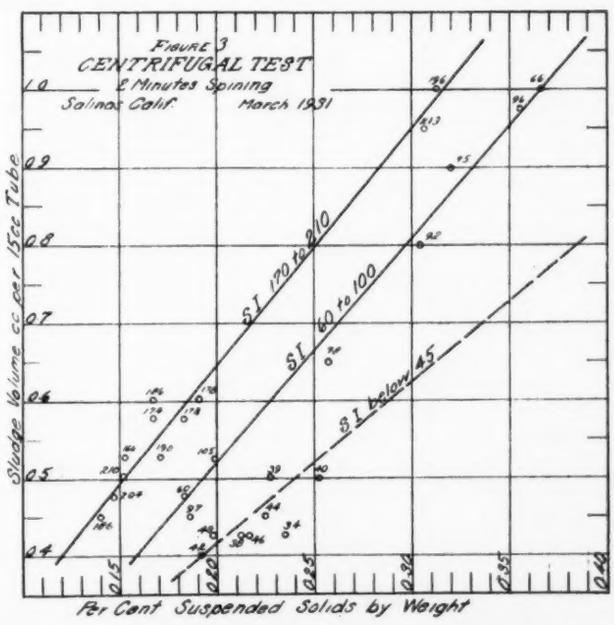


Fig. 3.—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

with rapid sludge removal. In small plants that do not have sludge reaeration this extra attendance is not justified and a very high, constant, rate of sludge withdrawal can be used throughout the 24 hours. When the plant is treating a strong sewage the daily sludge withdrawal may be actually equal to the sewage flow with no ill results and, possibly, some benefit. (At first it might appear that such an increase in volume of sludge return would unduly shorten the aeration period, however it may be shown mathematically that increasing the rate of return from 20 per cent to 50 per cent (equal sludge and sewage volume) cuts the nominal aeration period only 10 per cent because so much of the liquor in consequence passes through the aerators more than once.)

Most plants are not designed for sludge reaeration. If reaeration is used it is desirable to keep the rate of sludge withdrawal from the final tanks at a minimum, consistent with rapid sludge removal, in order to have the longest reaeration period, *providing it is possible to maintain some dissolved oxygen at all points in the reaeration tank.* If that can not be done then the rate of withdrawal *must* be increased so as to reduce the oxygen demand of the reaerating sludge.

Sludge Concentration Important

To intelligently divide the sludge withdrawal between return and waste it is necessary to make daily suspended solids tests on the mixed liquor, as previously discussed. If these results are below the amount of sludge desired the amount going to waste should be decreased and vice versa. Waste activated sludge should always be concentrated before introducing it into sludge digestion tanks. At most plants the only means of concentration provided is the introduction of waste activated sludge into the primary settlers. It has been the writer's experience that where this method is used better concentrations of primary sludge are obtained by wasting continuously over the 24 hours at a low rate than are obtained by wasting at a higher rate for a shorter time. This method of wasting excess activated sludge has many disadvantages,[21] particularly when the sludge is bulked. A better, though less common method entails the use of a separate tank, termed a sludge thickener, and the use of chlorine.[22, 23] Where a thickener is provided best results are obtained by feeding it with mixed liquor direct from the aeration tanks instead of with sludge withdrawn from the final clarifiers. The clear, chlorinated, supernatant from the thickener may be discharged to the incoming raw sewage, the return activated sludge or the final effluent. Either of the first two are preferable because of its beneficial action in overcoming septicity.

Troubles

Now just a few words concerning troubles. Sludge bulking is probably the most common trouble encountered with the activated sludge process. The term "bulking" has been used by some to cover the condition of sludge pouring over the weirs of final clarifiers, but the writer considers that an improper use of the term. A bulked sludge is simply a sludge that, after a given settling period, occupies a greater volume than would a normal sludge containing the same amount of suspended matter by weight. Bulking is best measured by the sludge index[9] as previously described. Whether or not a bulked sludge will pour over the weirs of final clarifiers depends, primarily, upon the design of those tanks. The more generous their design the higher can the sludge index become before the effluent is fouled.

It was previously stated that when oxidation lagged behind adsorption the sludge floc became so light that it would not settle properly, in other words, the sludge bulks. We have given six possible causes of oxidation lagging behind adsorption and suggested means of overcoming them. Any one of those six will cause bulking if not corrected. Certain microscopic, filamentous, growths will cause, or increase, bulking. Sphaerotilus is far the most common organism. Even though the sludge is constantly seeded with these organisms they do not flourish in the sludge if oxidation is keeping pace with adsorption, but if oxidation lags behind adsorption the sludge may become an ideal habitat for profuse growths. Correct the oxidation-adsorption balance and the number of Sphaerotilus will greatly diminish. Other filaments than Sphaerotilus may cause bulking, notably Cladothrix and Leptothrix, but their occurrence is so rare as to warrant no discussion here.

Bulking is not the only cause of excessive amounts of sludge passing out with the final effluent, although it is the most common one. There are two other causes. One is simply insufficient sludge withdrawal, the other is "sludge rising." Rising sludge is most commonly encountered in plants treating sewage high in nitrogenous matter (notably meat packing wastes) where nitrification is quite high. The sludge will settle rapidly in tanks or graduates, but will rise again in from 20 to 90 minutes. The sludge is lifted by accumulations of nitrogen gas. At some plants[24] it has been overcome by keeping the dissoved oxygen in the aerators very low, at others[16] it has been found helpful to increase the amount of sludge carried in the aerators.

Digester overflow liquor has caused considerable trouble at several activated sludge plants, among them Grove City. At most plants it is common practice to return digester overflow to the raw sewage, and, in a properly proportioned plant, the liquor will cause little or no difficulty providing its solid content does not exceed 0.2 per cent. If the overflow contains more than 0.5 per cent solids it turns primary clarifiers septic and covers them with gas-buoyed sludge. Under such conditions their effluent is very difficult to treat by the activated sludge process. At Grove City we have an overflow averaging well over 1.0 per cent solids. We add lime to it and turn it directly into the aeration tanks. The proper lime dosage, in our case, seems to be about 1 pound of lime to each 10 cubic feet of liquor. The liquor turns the aerators very dark, detracts from the appearance of the effluent, and unquestionably puts a tremendous burden upon the activated sludge process. However, we have been able to treat most of the liquor in this way although it seriously upset the plant when we attempted to return it to the raw sewage.

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PENNSYLVANIA WATER AND SEWAGE OPERATORS HOLD JOINT MEETING

Dinner at Old Washington Inn, Valley Forge

Here and There at the Inn Before Dinner

A stone wall conversation, a bridge game, some kidding over golf scores, etc., etc.

ANOTHER of the successful joint sectional meetings of the Pennsylvania Water Operators' Association and the Association of Sewage Works Operators of Southeastern Pennsylvania was staged on May 16th at Phoenixville, Pa.

In the forenoon golfing was the attraction to many. The Sewage Works Operators held a brief technical session at noon and adjourned to inspect the water treatment plant and the new sewage treatment works of the Boro of Phoenixville.

170 Present at Dinner

In the evening 170 members and guests were present at the dinner served at Washington Inn at Valley Forge. Following the dinner, over which Norman G. Young, Borough Manager of Phoenixville, presided as host and master of ceremonies, an illustrated talk was made by Francis S. Friel, Consulting Engineer of Philadelphia, relating experiences in constructing water supply and sewerage facilities for the U. S. Army Cantonment at Aberdeen, Md.

Under pressure of essential speed these utilities were designed and completed in a period of six months in the mire of mud and the blasts of winter. Ordinarily, not less than 18 months would have been required for the same job.

Phoenixville Hosts

Norman G. Young
Boro Manager

H. K. Malen
Supt. Water & Sew.

The water system involved putting down deep wells, construction of a filtration plant, 13¾ miles of mains 6 inch to 12 inch in size; and elevated tank. The sewerage system involved 15½ miles of sewers, a treatment plant, pumping station and outfall.

The 2½ m.g.d. filter plant is supplied with steel coagulating basins, and wood tub filters equipped with C. I. manifold and perforated laterals of red brass pipe. Elevated storage totals 750,000 gals. providing static head of 55 to 75 lbs. The grid system is completely looped and 1,000 g.p.m. to two separated fires is available at required nozzle pressures.

The sewage treatment plant is of the primary separate digestion type designed for 15,000. The effluent is chlorinated and pumped to Chesapeake Bay through an 18 inch force main of cast-iron pipe.

Mr. Friel then outlined standards of minimum requirements set for sewage treatment units in army cantonments.

Floor Show and Prizes

At the end came a snappy floor show and the award of golf and door prizes by "Casey" Jones, Chairman of the Committee. A special prize of a fine traveling case was presented to the host—Norman G. Young.

The next joint meeting of the water and sewage works operators' association is scheduled for September 26th in Chester, Pa., when the Chester Water and Sewerage Authorities will be the hosts.

EMERGENCY SUPPLIES

A Plan to Assure Their Identity and Continuous Availability

By M. C. SMITH
Chief Engineer
DEPT. OF PUBLIC UTILITIES
RICHMOND, VA.

WHILE many well informed persons appear to consider that there is but little to fear in the direction of sabotage of water works systems in America, yet the possibility of such outrages certainly merits serious consideration by those in charge of these systems. While it may be impossible to devise a single plan of defense that will prove to be effective and practical for all systems, the City of Richmond, Va., has adopted one that, as far as is known, is unique. At the suggestion of the editor of WATER WORKS AND SEWERAGE, this plan is being described, believing that the idea may prove of real value should its application ever be required.

On the theory that prevention is always better than cure, adequate safeguarding and protecting of the most vulnerable parts of the system is unquestionably indicated. But the distribution system, sprawling as it does over wide areas, presents a much more difficult problem. For the distribution system the only practical defense measures would seem to be those of cure rather than attempting impractical prevention efforts.

Plan Possesses Advantages in Normal Times

Fortunately, the plan here described is of as much benefit in the case of normal failures as with willful damage. In addition, the investment may be recovered at any time it is believed advisable to return to normal conditions. Briefly, the plan consists of assembling a carefully planned stock of the equipment used in the distribution system, and by identification marks and segregation from the normal stock, assuring the immediate availability of parts for repairs in case of need.

Segregation is obtained by placing the emergency supply within a locked protective type of fence, completely enclosing the area in which the items are stored. The identification mark on each piece may be superfluous, but is a white cross within a circle. The arrangement of items is carefully planned to permit the derrick trucks reaching any piece without the necessity of moving any other, and each type of equipment is stored in groups and arranged as to size.

The Richmond mains are of cast iron and include up to 36 inches in size. The smaller sizes are in such constant demand that an adequate stock of valves and fittings is necessary for normal operation. Also the loss of smaller mains is not likely to cause nearly so serious interruption of supply as would the loss of a large feeder. It was considered sufficient to limit the stock to parts for the 36-inch to the 12-inch sizes, inclusive. In pipe, the number of lengths carried is from a minimum of one hundred and twenty (120) feet to a maximum of two hundred and forty (240) feet, depending upon the quantity in service and the relative vulnerability.

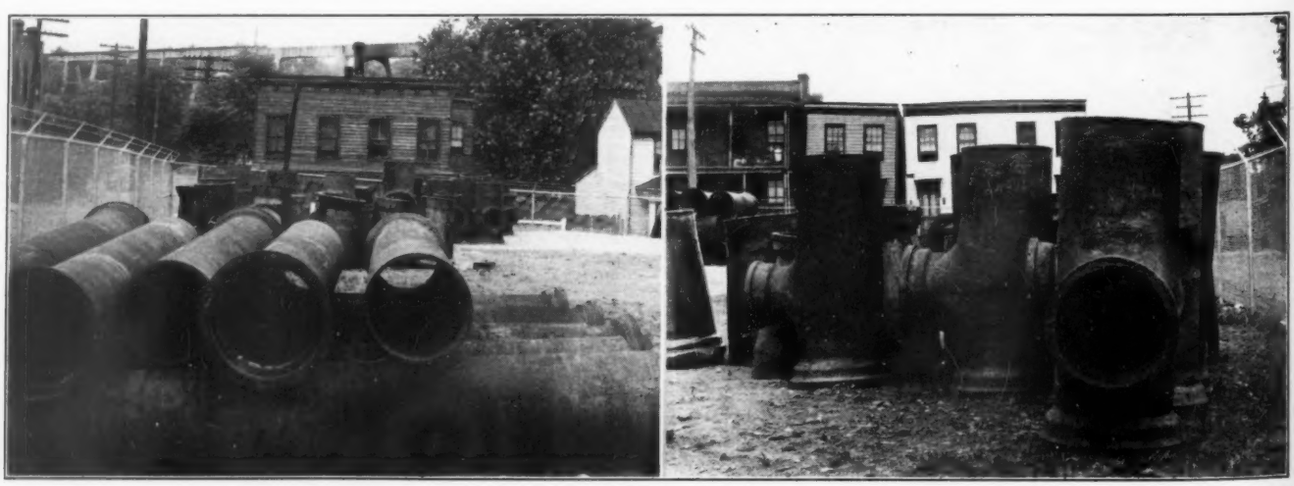
Valves Can Be Limited to Two Sizes Only

The investment in valves is limited to two sizes. Such is possible because with the availability of reducers, mains of any diameter may be valved from the two sizes. For mains of 24 inches and larger, a 24-inch valve will be used, while for mains of from 12 to 20 inches, inclusive, the emergency valves will be of the 12-inch size.

And, finally, effort is now being made to obtain flexible steel piping, similar to that used in England, which may be used to restore emergency service should the damage to pipe supports render the standard repair impractical.

The one primary attribute of the plan is that of assuring the immediate availability of materials needed to repair *any* damaged main in the system. For this reason, no one may take out *any* part of the emergency stock, except by order of no less responsible official than the Engineer in Charge of Distribution.

To this end we have considered that the distinctive markings on the special emergency stores and equipment may have a value in addition to their segregation in the special enclosure.



Two Views of the Emergency Equipment in Special Yard
Note arrangement of items to permit derrick trucks reaching any piece without moving others.

A PERPLEXING CHLORINATION PROBLEM

And How It Was Solved by Departure from Usual Design

J. H. LE CHARD
Chief Engineer
ATLANTIC CITY SEWERAGE CO.
ATLANTIC CITY, N. J.
AND
G. W. BENBURY
Service Engineer
PENNSYLVANIA SALT MFG. CO.
PHILADELPHIA, PA.

THIS relates to an unusual chlorine conveying problem at the Atlantic City Sewerage Company's City Island treatment plant. City Island is connected to the mainland only by a narrow foot bridge about 1,500 ft. long, and all heavy materials must of necessity be delivered to the plant by water transport. When decision was made to chlorinate the sewage, the transportation of liquid chlorine to this plant became a major item in the planning. On this account chlorination of raw sewage at the more accessible pumping station located on the mainland was first attempted.

During the summer of 1939, plant scale chlorination at the Baltic Avenue pumping station showed that taken alone this was not a sufficiently dependable method of reducing the bacterial population in the plant effluent. Fifty tons of chlorine were added to the sewage over a period of 35 days and it was apparent that in the long pressure main chlorine residuals were too difficult to maintain. In addition the chlorine demand under the pressure and conditions in the inverted syphon exceeded that predicted on the basis of demand tests made on sewage reaching the plant through this same pumping main. It was evident that chlorination must be accomplished at the plant itself if effective results were to be obtained through single point chlorination. Further, the matter of chlorine economy was to be considered too.

Suggested Solutions

A study of the several means of getting chlorine to the island resolved the problem into four possible solutions.

(1) One hundred and fifty pound cylinders, having a gross weight of 242 lbs. each could be hand trucked over the foot bridge to the plant. This was promptly discarded. The requirement of roughly 3,000 lbs. of chlorine daily placed the job in the ton container class, both with respect to unit cost of chlorine as well as the awkward problem of connecting and disconnecting 20 cylinders daily.

(2) Ton containers could be transported to the island on barges. This was eliminated from further consid-

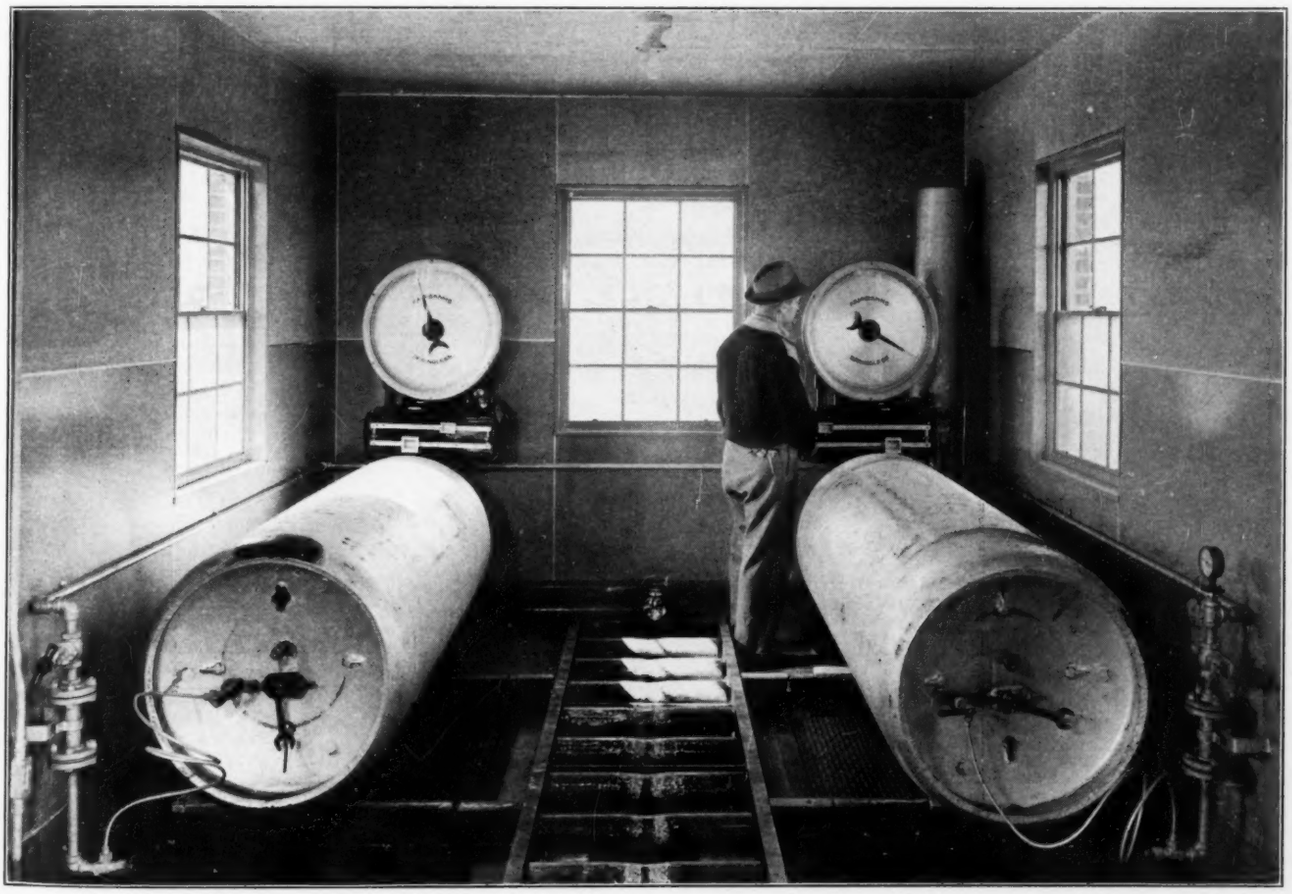


Fig. 1.—Ton-Containers Feeding Chlorine in Liquid Form Through 1600 ft. of Pipe Line to Atlantic City Chlorinators
Expansion cylinder on line is seen in right corner; stop-flow safety valves are seen on the right and left walls close to the containers

eration because the apparatus and labor involved in moving 45 ton containers (gross wgt., 3,600 lbs. each) every month created quite an operation and navigation problem.

(3) Ton containers could be housed on the mainland and unloaded by withdrawing chlorine gas and conveying it to the island through a pipe line attached to the foot bridge. This solution, although promising, was finally set aside because of reliquefaction probabilities in the long line exposed to the elements. Effective insulation, preheaters, liquid traps, and other devices commonly employed to combat liquefaction in chlorine gas lines, were obviously inadequate to cope with the problem offered by 1,600 feet of undulating pipe almost entirely exposed to the weather.

(4) The ton containers could be housed on the mainland and discharged by piping the liquid chlorine, as such, from the containers to the island. The disadvantages of this method appeared to be less ominous than the other three solutions and this plan, involving a materially smaller diameter pipe line than would have been required for transfer of gaseous chlorine, was the scheme adopted.

Considerations in Designing a Liquid Chlorine Line

The principal problems involved in the design were (a) construction of a chlorine-tight pipe line supported on a wooden foot bridge constantly subject to wind and tide vibration, (b) provision for the thermal expansion and contraction of this long exposed line, (c) protection of the line from hydrostatic rupture due to expansion of liquid chlorine which might be trapped therein, and (d) provision of an essential safety device which would automatically stop escape of liquid chlorine from the ton containers in case of line breakage due to coastal storms, run-a-way barges, etc.

Fig. 2.—Looking Down the Foot Bridge Toward City Island

Along the left is seen a section of the 1600 ft. liquid chlorine line loosely strapped in place to allow expansion and contraction.

A Chlorine-Tight Line

Considering that the chlorine pressure in the line is controlled by the temperature of the containers, properly sheltered on the shore, a peak probable ton container temperature of 105° F. was selected. This corresponded to a chlorine vapor pressure of 154 pounds gauge or a total pressure of 176 pounds when the effect of inert gases were considered on a fresh container stored at this temperature.

Obviously such probable pressure required the use of extra strong pipe and fittings, such as are normally designed for 250 lb. working pressure being selected. The provision of these heavier pipe and fittings together with insistance on good workmanship yielded a chlorine tight line. In the actual construction of the line, considerable trouble was experienced with pipe fitters who did not appreciate the necessity of clean, sharp threads cut full length and full depth and jointed with litharge and glycerine or white lead and oil. Poor workmanship and the use of proprietary jointing compounds caused a number of leaks during the initial operation of the line. In every case these headaches were eliminated by the inspector making certain that each joint was reworked and secured according to specifications. The authors cannot over-emphasize that the best mechanical work and strict adherence to luting specifications must be enforced on pipe fitters erecting chlorine pipe lines. Care must also be taken to make certain that *tapered thread* couplings are furnished with the pipe. A number of pipe companies normally supply straight thread couplings. These are not satisfactory for chlorine lines.

Contamination by organic impurities from pipe linings and exuding luting compounds is of such importance that it must not be neglected. Liquid chlorine will partially dissolve oils and the lacquer of pipe coatings, later deposting compounds in pipe, valves, of the gas phase of the system. Before laying the pipe line, the interior of each length of pipe was cleaned with carbon tetrachloride, and all valves and fittings were degreased with this solvent. Care was also taken to prevent luting material from entering the pipe at threaded joints.

Thermal Expansion Protection

A flexible U-bend type of expansion absorber was specified rather than the slip-joint device, since the avid attack of chlorine on all fluid greases and oils made the lubrication of slip-joints out of the question.

For the exposed 1,500 feet of pipe line, which is virtually in a straight run along the bridge, the calculated increase in length for a temperature rise of 140° F. is 16.95 inches. To absorb this, five expansion bends were designed, having a radius of curvature of 1′3″ and a length, after forming, of 5′6½″—see Fig. 4. These were spaced to absorb equally the pipe expansion. It was necessary to fasten the pipe securely on each side of the expansion bends and then

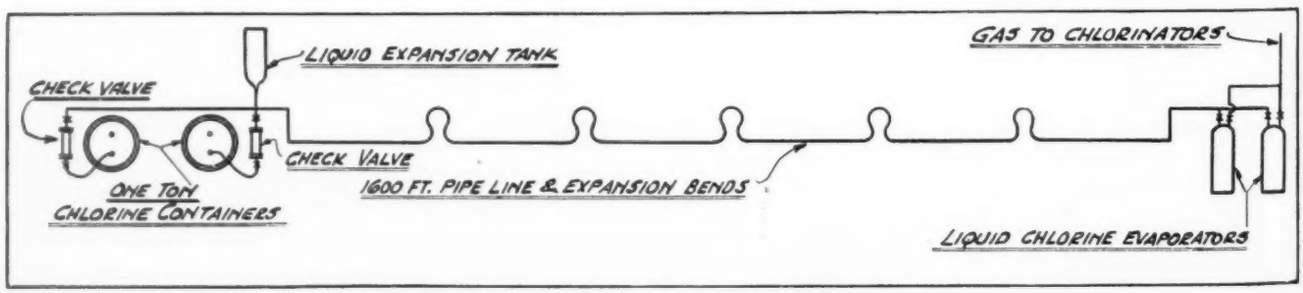


Fig. 3.—Schematic Sketch of the Liquid Chlorine System of the Atlantic City Sewerage Co.

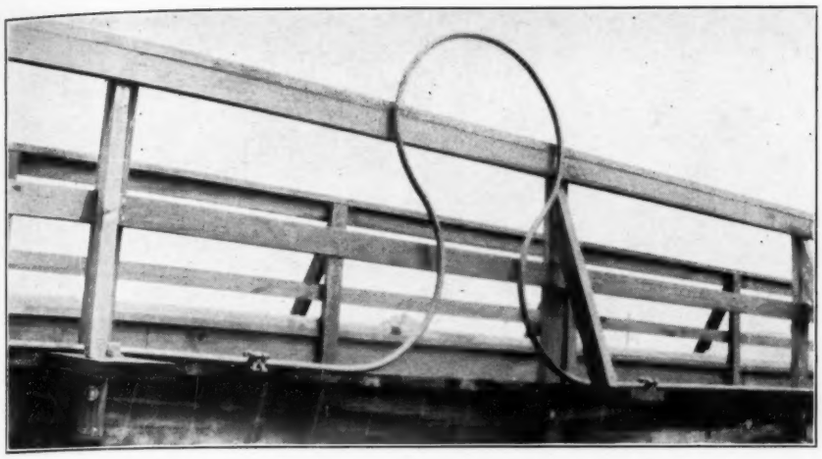


Fig. 4.—One of the Five Expansion Bends
(For method of anchoring see text.)

cold-spring the bends one-half the distance of the calculated expansion to be absorbed by each bend. Anchorage was accomplished by welding a base plate to the pipe at least 15 feet from the start of each bend and bolting the base to a 2″ x 6″ wood floor member of the bridge. Connections of the expansion bends to the pipe on each side were made through four-bolt ammonia flanges, using compressed asbestos gaskets. Except for the one anchor plate before each expansion bend, the pipe was allowed free movement at all other points through use of over-size pipe straps. It is interesting to note that bridge construction did not permit readily the usual method of laying the expansion bends horizontally. Instead the bends were placed in a vertical position along the line. This deviation from conventional practice results in no operating difficulties, but it does increase the time required for emptying the system prior to shutdowns for repairs.

Liquid Chlorine Expansion

The not-generally understood expansion characteristic of liquid chlorine with temperature rise necessitates special design precautions in order to avoid hydrostatic rupture. For example, a container 88 per cent liquid full at room temperature becomes 100 per cent liquid full at 154° F. due solely to this expansion. Likewise, a pipe line 100 per cent liquid full with valves closed at each end will, upon substantial temperature elevation, be subjected to unlimited hydrostatic pressure, resulting in rupture.

In the chlorine industry it is common practice to provide expansion chambers in long liquid chlorine lines. These usually consist of closed chambers mounted above and connected to the highest point of the line. The calculations of the volume of the expansion chamber needed for this line follow. They indicate that a 150 pound chlorine cylinder, having a total volume of 1.925 cubic feet, and connected in inverted position to a high point of the line to serve as a gas chamber, will provide adequate protection against hydrostatic rupture of the line.

Calculations of Required Volume of Expansion Tank

(1) Internal volume of pipe line—¾″ extra heavy pipe 1,600 feet long—internal area = 0.4324 sq. in.

$$\text{Volume} = \frac{0.4324 \times 1{,}600}{144} = 4.8$$

cu. ft.

(2) Internal volume of 150 lb. chlorine cylinder is 1.925 cu. ft.

Volume = 1.925 cu. ft.

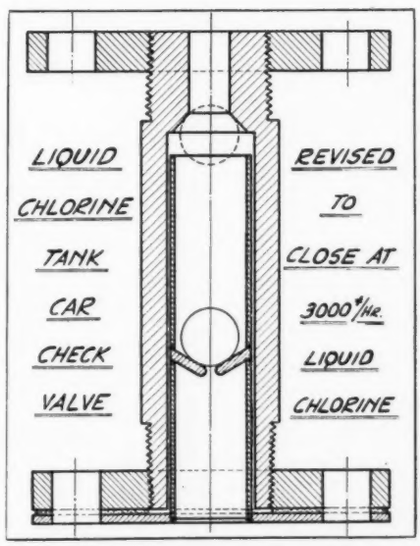


Fig. 5.—Stop-Flow Safety Valve
A dependable time-tested chlorine tank-car unit modified to function under Atlantic City conditions

(3) Total volume of pipe and cylinder is 4.8 + 1.925 = 6.725 cu. ft. Consider cylinder connected to high point of the line and half full of liquid chlorine at 40° F.:

$$\frac{1.925}{2} + 4.8 = 5.762 \text{ cu. ft.} = \text{volume}$$

of chlorine contained in pipe and one-half of cylinder.

(4) Expansion of liquid chlorine from 40° to 135° F.—Liquid chlorine at 40° F. has density of 90.9 lb. per cu. ft. Liquid chlorine at 135° F. has density of 80.4 lb. per cu. ft.

From 40° F. to 135° F., 5.762 cu. ft. of liquid chlorine will expand to:

$$\frac{90.9}{80.4} \times 5.762 = 6.51 \text{ cu. ft. at } 135°\text{F.}$$

But the total volume of pipe and cylinder is 6.725 cu. ft., therefore, the 150 lb. liquid chlorine cylinder should be sufficient for any normal liquid chlorine expansion in the system.

Chlorine Escape Protection

One of the first questions usually asked on a chlorine installation is, "What will happen if we lose a ton of chlorine?" The usual answer to this is simple and truthful, consisting merely of the observation that it is physically impossible for a ton of chlorine to be quickly lost as a gas. The refrigeration of the container by escaping gas slows down the discharge to the point where complete emptying is a matter of days rather than minutes.

Plants withdrawing chlorine as a liquid, however, are faced with the very real possibility of the loss of astonishingly large quantities of chlorine in a relatively short time. Being 450 times more dense than gaseous chlorine, and refrigeration not being created, escaping liquid chlorine can completely empty a ton container in a matter of minutes. Because of the exposed location of the pipe line, it was necessary that an automatic safety device be provided to stop the liquid chlorine flow in case of line breakage. A vertically operating ball check valve was selected as the most promising safety device.—See Figs. 5 and 6. The weight of the ball and the annular space between the ball and the cage control the rate of flow of liquid through the check valve so that the ball remains at rest at maximum operating rates, but is lifted up to its seat in case of flow increase beyond the design rate.

Check valves constructed for liquid chlorine tank car service form the basis of design for those employed on

this installation. These valves are built to close when liquid chlorine is withdrawn from a tank car at the rate of 8,000 lbs. per hour. They consist originally of a Monel cage threaded for 1¼ inch male pipe connections at each end and having a ¾ inch diameter ball retained inside by a Monel metal pin inserted through the diameter of the cage. Revision for this installation consists of removing the Monel pin and welding tight the two opposing holes, placing a sleeve fitted with retaining pins inside the cage and adding steel companion flanges to each end. The same ball functions at the lower closing rate in the reduced annular space between it and the inserted sleeve. Details of this valve are shown in Fig. 5 and their location in Fig. 1.

Based on the plant's present chlorinator capacity, the maximum chlorine withdrawal rate for any ton container connected alone might be as high as 8,000 pounds per day. Normal rushing of liquid chlorine into the line upon turning on a fresh container soon proved that the original design figure of six times the maximum expected withdrawal rate provided a much too sensitive ball. This

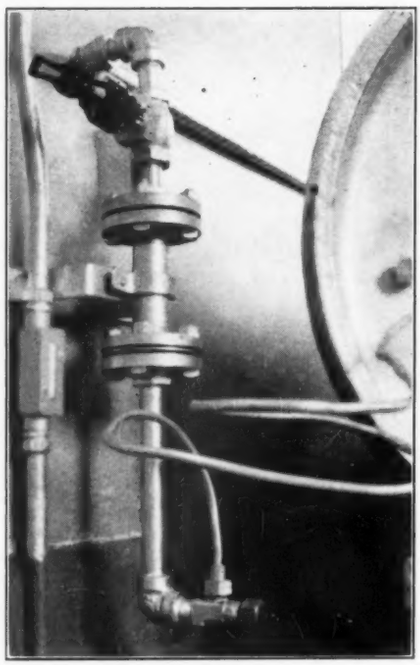


Fig. 6.—A Close-Up of the Safety Valve

was increased 50 per cent by trial and error experimentation and today the closing rate is 3,000 pounds of liquid chlorine per hour. This appears to be sufficient to keep the ball in repose during normal fluctuations in flow and yet it provides sufficient sensitivity to insure the ball lifting in case of heavy discharges.

The Final Installation

The chlorine equipment installation as installed consists essentially of the following:

1. A ton container storage platform and scale house on the mainland. In the scale house are two scales, each holding a one-ton container of liquid chlorine which connects to the pipe line through a line valve and ball check valve. The inverted expansion tank (chlorine cylinder) connects to the pipe line at the junction of the two ton container lines.

2. A run of 1600 feet of uninsulated ¾ inch extra heavy black iron pipe, traversing the full length of the foot bridge between mainland and island, and equipped with 5 expansion loops.

3. A chlorinator building on the island housing liquid chlorine, evaporators and vacuum types, solution feed chlorinators.

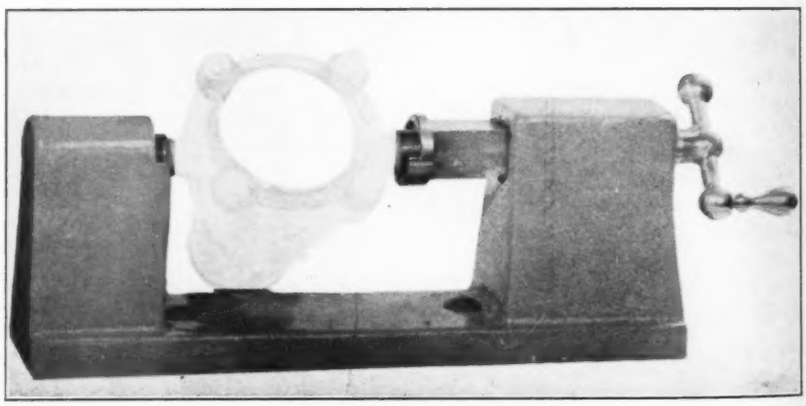
A Prize Winning METER VISE

"Dear Ed:"

I have noticed lately that an increasing interest has been prevailing in the operation of water-meter repair shops. You might be interested in knowing something about a handy meter vise that has been designed and perfected in the shops of the Oklahoma City Water Department. During the past ten years this vise has saved an endless amount of time and effort for the workman, and has caused him to "take pride" in his work. It has been of such great aid in improving the efficiency of the shop that the Department now has a meter vise for each meter mechanic.

The vise is of lifetime cast iron construction and takes up only a small space on the workbench. It can be bolted to the bench and out of the way when working with something else. Its operation is simple and requires very little time—"just a twist of the wrist" to operate this meter vise, is all that it takes.

As the picture I am sending along shows, the vise holds either a ⅝" or ¾" meter rigidly, and in whatever position desired, for repairing. It allows the workman to work with both hands, thereby *doubling* his working capacity. It has been found through ten years' experience that more meters can be repaired in less time and with much greater accuracy with this vise than by any other method.



A Handy Meter-Shop Accessory

We are proud of the fact, also, that our "O. K."* Meter Vise won the gadget prize contest conducted by the Southwest Section of A.W.W.A. at the Tulsa meeting last Fall.

The vise can be made with our patterns, for about $25.00 each.

Yours very truly,

M. B. CUNNINGHAM,

Superintendent and Engineer, Oklahoma City Water Department.

*P.S.—We call it the "O.K." for two reasons: first, because it is, and also because the letters "O K" are the first two in our town—Oklahoma City.

THE PRESERVATION OF SEWAGE SAMPLES

GEO. E. PHILLIPS
Chemist

and

W. D. HATFIELD
Superintendent

DECATUR SANITARY DISTRICT
DECATUR, ILLINOIS

ALTHOUGH it is generally appreciated that samples of sewages and effluents are not stable and should be analyzed as soon as possible after collection, many plant operators are careless in the preservation of the samples they collect. Standard Methods of Water Analysis, 8th Ed. (A. P. H. A.) on page 126 gives the following instructions: "Samples for the determination of relative stability and biochemical oxygen demand * * * should be kept in a cooler at 4°-10° C. during the compositing period."

In view of the data presented herein, it appears probable that such a latitude in range of temperature is too liberal.

In studying the possibilities of using automatic samplers, and in comparing the automatically collected sample with a sample composited hourly and cooled to about 10° C. in a water bath, through which cool well water circulated, excellent agreement of the B.O.D.'s was obtained in cool weather when the air temperature was about 10° C., but in summer weather the B.O.D.'s of the 24 hour automatic samples were much lower than those of the hourly composite kept in the cooler.

Experience with Automatic Proportional Sampling

Our Martin-type automatic sampler collected 5 ml. samples about every minute, the frequency being controlled with a speed regulator so that the volume collected was proportional to the flow. The automatic samples were collected during 8 hour shifts, remaining in a shaded compartment at outside air temperature during the collecting period. At the end of the shifts the samples were placed in the 10° C. water cooler, and at 8 o'clock the following morning the 3 shift-samples were poured together for analysis. This sample was compared with the regular hourly composite sample, which was made by collecting a 4 oz. sample hourly and pouring it into a gallon bottle which was kept in the 10° C. water cooler.

No real advantage was found in the proportional flow sample, because the normal flow of sewage at Decatur only varies between 9 to 12 m.g.d. and the concentration of the night sewage is about as strong as that of the day's, therefore, in our case proportioned samples are not necessary. In the summer the automatic sampler was unreliable, giving results 25 to 30 per cent *lower* than the hourly hand collected samples which were better preserved at 10°-12° C. Because of the findings and the cost of refrigerating the automatic sampling compartments of the 4 or 6 samples required at Decatur, automatic sampling is not justified.

A Study of Storage Temperatures

These results led to a study of the effect of storage and temperature on the B.O.D. of sewage and effluent samples.

The procedure was to collect a large grab sample and divide it between three one-gallon sample bottles filled about ⅔ full, and chilled *immediately* to 5, 20 and 37° C. By using heat or ice and salt as the case required, these temperatures could be attained within five minutes. The bottles were held at these temperatures and samples therefrom analyzed hourly or more often. During 1938 and 1939 about 30 different samples of sewage, effluent, starch wastes, and sewage-waste mixture were studied. Although the percentage change in the analyses vary with individual samples, the decrease in B.O.D. and increase in suspended solids is very consistent. Some of the results from this study are shown graphically in Figure 1.

The data plotted at the top of Figure 1 is on two samples collected on Jan. 5th and 13th, 1938. The former was treated as described above and the latter was chilled or warmed and siphoned into 250 ml. glass stoppered B.O.D. bottles, water sealed and incubated at 5, 20 and 37° C. It would have been more desirable to have had the two series of tests made on the same grab sample, but this was not possible because of limited incubator space. However, the two samples had original B.O.D.'s of 190 and 200 p.p.m., respectively, and are sufficiently alike to be compared. There was no dissolved oxygen or nitrates in the sewage of the 5th or 13th, and the drops in the B.O.D. of 10, 13 and 20 per cent obtained in the stoppered samples must have been due to delayed enzymic action of the aerobic organisms, or to anaerobic decomposition which lowered the B.O.D. without the presence of dissolved oxygen.

The sample collected Oct. 28, 1938, revealed a similar drop in B.O.D., although the drop obtained at 20° C. was not as large as usual. The increase in suspended solids on storage is shown in the curve to the right. The same ultimate rise, from 170 to 205 p.p.m. of suspended solids was obtained at all three temperatures, but the 37° C. sample exhibited this increase in 2 to 4 hours, while at the lower temperatures the rise was more gradual. In the lower right hand corner of Figure 1, similar curves are shown for a strong starch-waste sewage mixture stored at 20° C. A large part of the B.O.D. loss is from the soluble B.O.D., but this does not account for the total loss. The increase in suspended solids runs to about the same percentage as that obtained on the October 28th sample.

The sample collected Nov. 9, 1938, illustrates the possibility of combining both low temperature, and either low pH or a mild germicide, to preserve samples. This sample had a pH of 5.8 due largely to corn products wastes containing SO_2 in solution. The effect of either the lowered pH or the SO_2 is to delay the rapid loss of B.O.D. during the first 6 hours and at 5° C. to make the loss almost negligible. On this sample we also have a parallel run in glass stoppered bottles in which the combined low pH (or germicide), low temperature, and absence of air. have practically stopped the loss of B.O.D. This suggests a most interesting research problem, but one which requires the detoxication of the germicide in the sample and proper seeding of the diluted sample for the B.O.D. test. The authors felt they did not have time to pursue this phase further at that time and were satisfied with developing a cooler in which hourly samples could be cooled immediately to 3-4° C.

In the lower left hand corner of Figure 1 is a typical curve on a

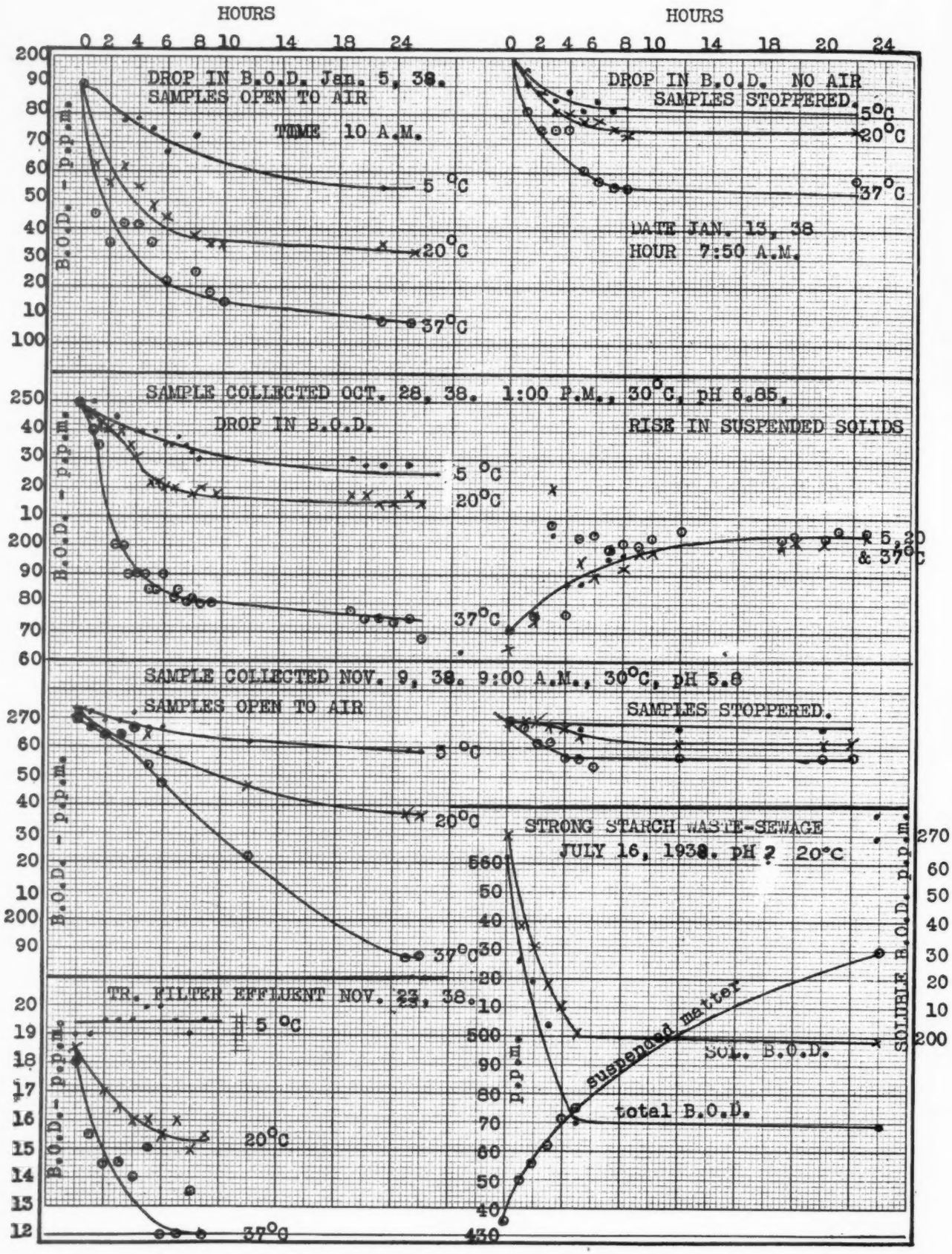


Fig. 1.—Progressive Changes in the B.O.D. and Suspended Solids of Samples of Sewage, Effluent and Industrial Waste on Standing

trickling filter effluent showing the same general temperature effect during the first 10 hours of storage as that obtained on sewages and primary effluents. The p.p.m. reduction is small, but the percentage reduction is about the same as that of sewage samples.

A Cooler of Interest

These convincing results lead us to discontinue the old tap water cooler and purchase a mechanical pop bottle cooler (Figure 2)* in which we could immerse the samples in water maintained between 3-4° C. The cooling efficiency of water is much greater than that of air and since the first few hours are the most important, the water cooler is much more effective than the air circulating refrigerator. We found summer samples (30° C.) required 2 to 3 hours to cool down to below 5° C. in a refrigerator.

Better results could be obtained by stoppering the hourly samples to exclude air during storage at 3-4° C., but this entailed the storage of 96 to 144 hourly samples which had to be composited the next morning before the samples could be analyzed. This technique did not seem practical at Decatur, so we sacrificed a little in accuracy and pour the hourly 4 oz. samples into large mouth glass one-gallon cream jugs which are about two-thirds submerged in the cold water. This almost immediately cools the samples to 3-4° C. and maintains the samples at that temperature until the composited sample is analyzed the next morning. These cream jugs are ideal sample jars because the large 4 inch mouth allows easy access for filling or cleaning and allows the introduction of a slow speed mechanical stirrer for thorough mixing of the sample (Figure 3) during the withdrawal of aliquots for analysis by pipette or siphon. This obviates the question of "gentle shaking" and settling of heavier solids while a sample of aliquot is being drawn from the bottle. The large mouth cream jugs are very inexpensive, selling at $4.56 a dozen at the time of our last purchase.

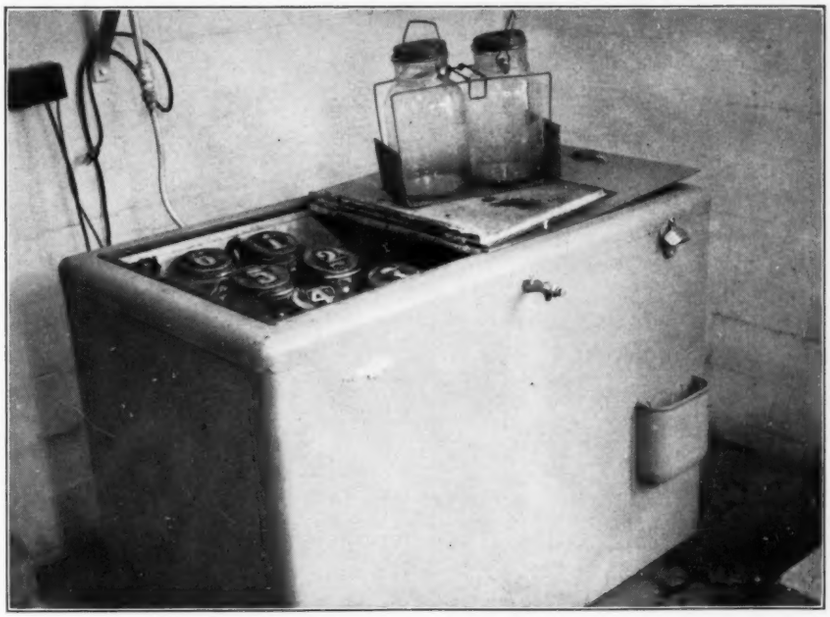


Fig. 2.—Pop-Bottle Cooler

Capacity is 3 sets of 6-one gallon 4-in. mouth cream jars. In this "Frigidaire" cooler samples can be maintained between 3 and 4° C. without difficulty.

Storage Drop in B.O.D.

The very rapid loss of B.O.D. at 37° C. explains a condition which has always existed at Decatur. Because of the large proportion of corn products waste in the sewage, the efficiency of plant operation is often expressed by the removal† of B.O.D. by the various steps in purification. This removal is calculated on a weighted basis by calculating the population equivalent removed by each step in the process each day. The average monthly results are shown graphically in Figure 4. In this figure the removal by the Imhoff tanks is indicated by the letter I, the aeration tanks by A, the trickling filters by F, etc. The point we wish to emphasize, however, is the drop in total population equivalent during the summer months. Although this reduction is partially due to a reduced corn grind in July and August, still the amount of the reduction in sewage strength cannot be wholly accounted for in this way. The sewage temperatures are about 22 to 23° C. in the winter, but in the summer the temperatures are 37-38° C.

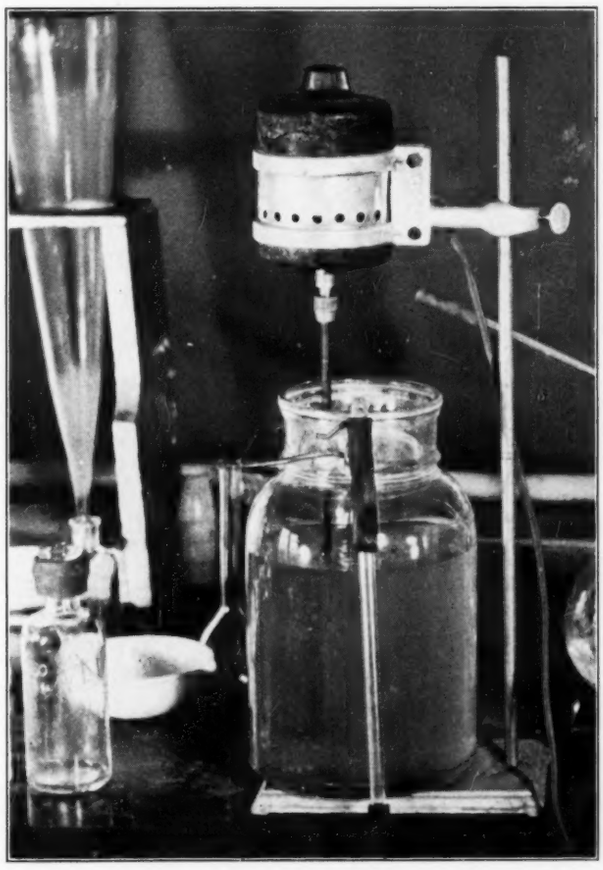


Fig. 3.—Gallon Sample Jar and Stirrer

Twenty-four hour composite sample being mechanically stirred, while aliquot portions for analysis are taken with pipette or syphon.

The time of flow from the industry to the sewage treatment plant is about 3 hours. In that length of time and at 37° C. one might predict a loss of B.O.D. of about 20

*Frigidaire @ $114.03.

†It is realized that the expression "percentage" removal of B.O.D. between the raw sewage and the final oxidized effluent has certain theoretical objections; nevertheless, it is a handy yardstick and the error introduced is to decrease the total efficiency and is therefore conservative.

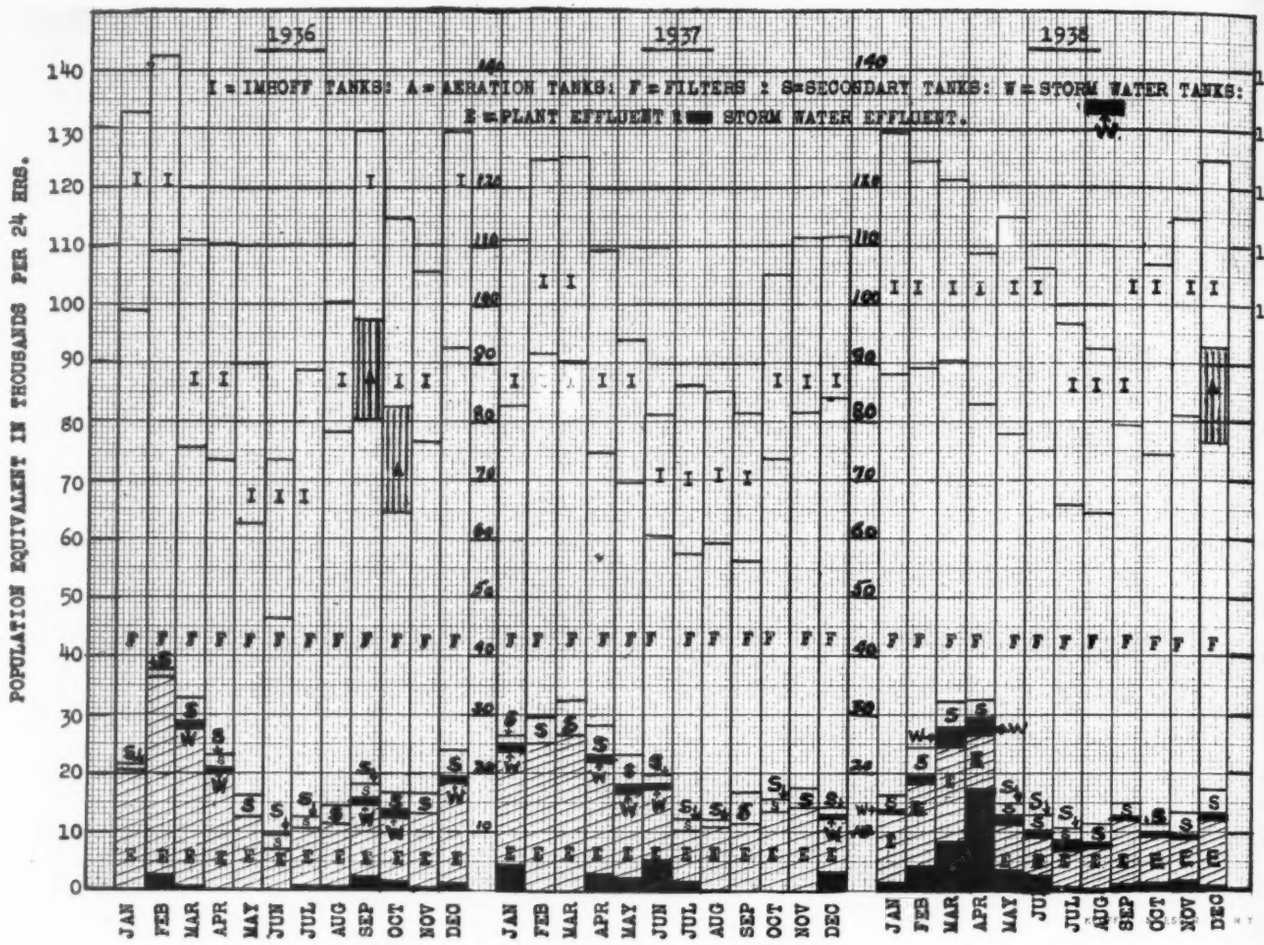

1936
1937
1938
I = IMHOFF TANKS: A = AERATION TANKS: F = FILTERS: S = SECONDARY TANKS: W = STORM WATER TANKS:
E = PLANT EFFLUENT: STORM WATER EFFLUENT.
POPULATION EQUIVALENT IN THOUSANDS PER 24 HRS.
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Fig. 4.—Performance Graph of Decatur Plant
(Removals expressed as population equivalent in thousands.)

per cent while the waste flows through the sewers and interceptor to the plant. There is some purification in the sewers in the winter (with the sewage-waste temperature of 20-23° C.) but the effect is almost doubled in the summer time at the higher temperatures. If 20 per cent is added to the values observed during summer months the total population equivalent would be about the same the year around.

Summary

1. The B.O.D. of sewage and effluent samples will decrease very rapidly (20 to 40 per cent) during the first 6 or 8 hours of storage, unless the sample is immediately chilled to less than 5° C.

2. Suspended solids increased about 20 per cent during 24 hours storage at all temperatures, although there was some delay in the natural flocculation during the first few hours at 5 and 20° C.

3. Automatic samplers are unsatisfactory unless they are designed with a refrigeration compartment that will keep the collected samples between 3 to 4° C.

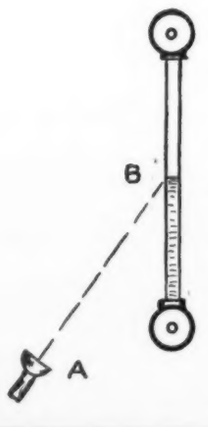
4. A cooler and sampling technic is described for keeping composite samples at 3 to 4° C. A still better technic is mentioned wherein each hourly sample is kept in a glass stoppered bottle away from the air and at 3-4° C., and the individual samples poured together the following morning for analysis.

5. The possibility of using both a lowered pH or a mild germicide combined with low temperature to preserve samples is suggested.

A VALUABLE GAGE GLASS KINK*

Fasten a bright flash or projector type light in position A, below the gage (not above), so that the light will shine on gage glass B.

Then examine the result from various positions in the room. You will find that when the light is placed in a certain position the liquid level will "stand out" most clearly. It will have the appearance of a "band of light" and will be easily seen.

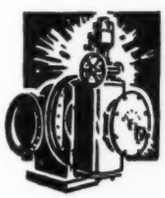


This is a worthwhile safety precaution as well as a time saver. A permanent light placed in position A will very likely result from your experimentations and will prove to be a valuable adjunct.

*Contributed by W. F. Schaphorst, M.E. Newark, N. J.

Valves

by SMITH



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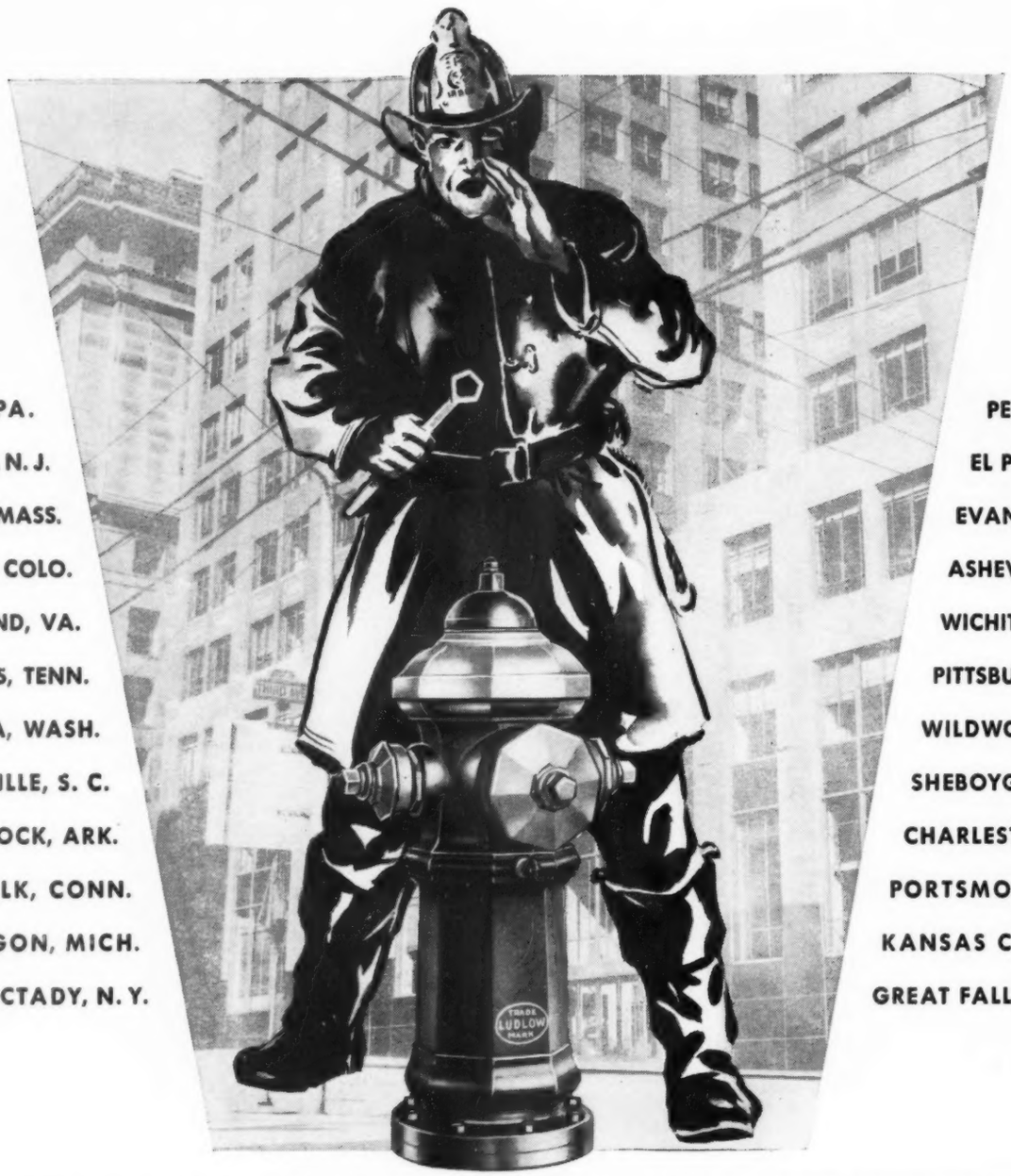

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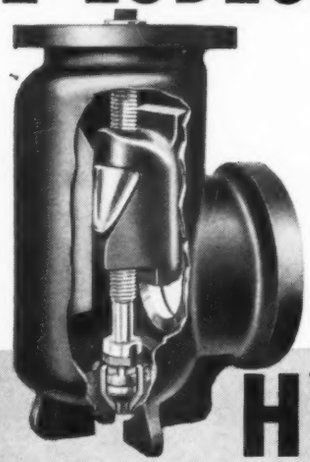

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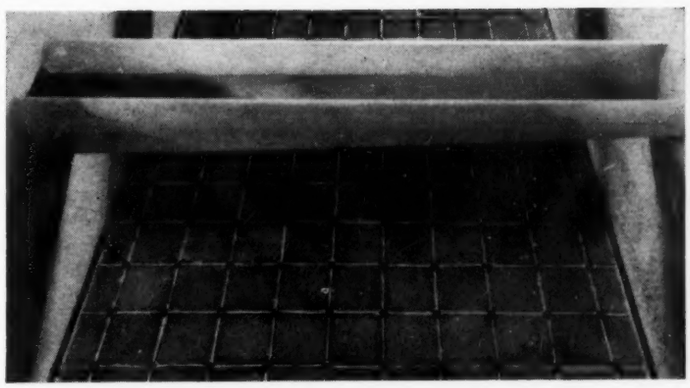

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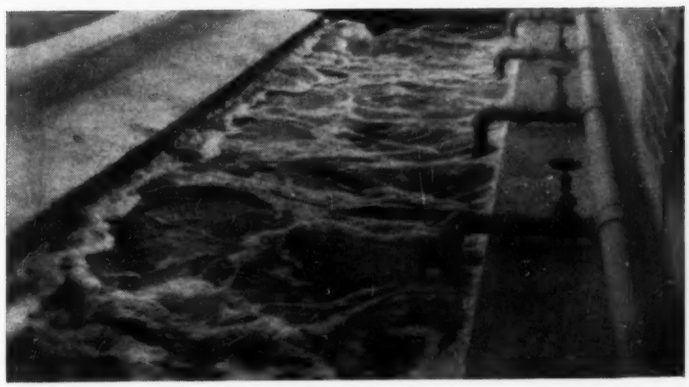

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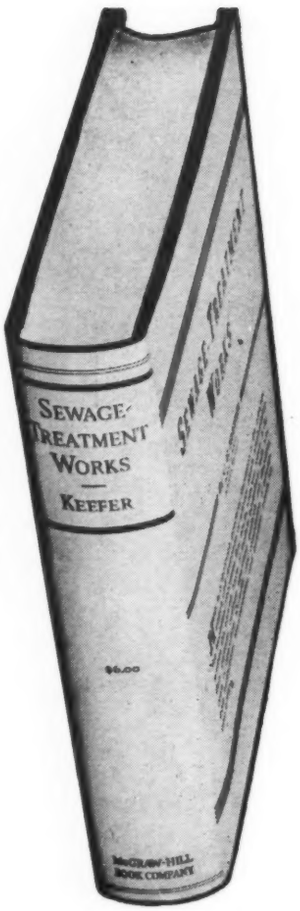

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MEASURING PULSATING FLOW ACCURATELY

Suggested Methods for Damping Pulsations

By WILLIAM MELAS
Cochrane Corporation
PHILADELPHIA, PA.

REGARDLESS of the type of flow meter used, where there is pulsating flow involved, it is generally impossible to obtain readings which are directly proportional to the rate of flow. However, precautions may be taken which will reduce the pulsations so that only small errors in the readings will result. Pulsating flow is generally encountered in systems where reciprocating engines, pumps, and compressors are used. The intermittent action of such units creates pressure and velocity waves in the fluid, whether it be liquid or gaseous. The waves or pulsations invariably increase the flow meter readings, not because of the oscillation of the pen back and forth on the chart, but because of the inability of the recorder to follow accurately each pulsation.

The magnitude of inaccuracy caused by pulsating flow depends upon the frequency and degree of pulsation, the volume and other characteristics of the piping and the compressibility of the fluid. However, in any case, it is highly important that pulsations be damped or eliminated in order to measure the flow accurately. The following arrangements, which successfully neutralize the pulsations and result in highly accurate readings, are recommended.

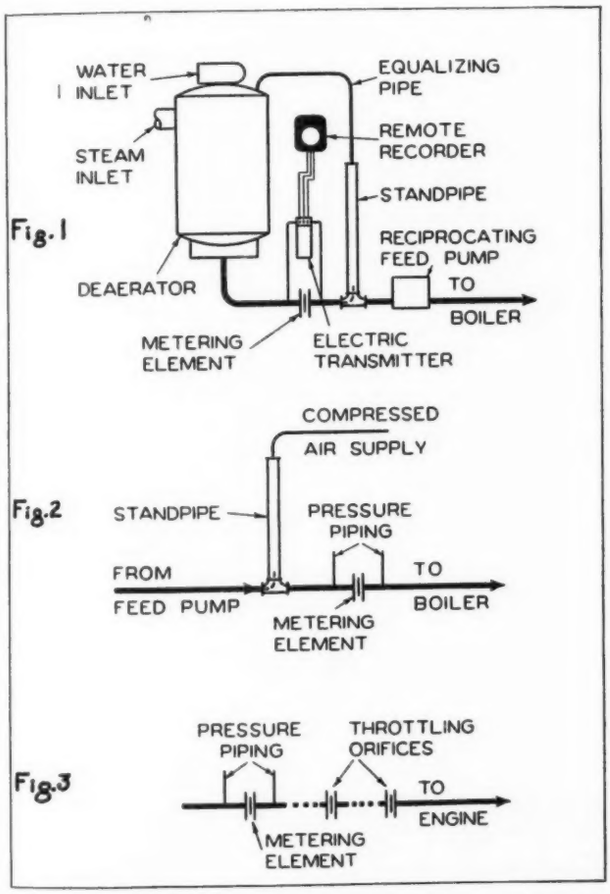


Fig. 1. Method of Installing Flow Meter in Connection With Reciprocating Boiler Feed Pump and Open Heater So That Error Due to Pulsations Is Eliminated. (Patented.)
Fig. 2. Air Chamber Arrangements for Damping Pulsations of Water or Other Liquids When Metering Element Is on Discharge Side of Pump.
Fig. 3. Use of Throttling Orifices to Damp Out Pulsations When Metering Steam, Air or Gas.

Orifice on Suction Side of Reciprocating Pump

The method shown in Fig. 1 enables a flow meter to measure accurately water taken by a reciprocating pump from an open feed water heater or other receptacle having a free water surface.

A stand-pipe located between the pump and orifice is vented back to the heater and absorbs the pulsations created by the pump. While the water level in the standpipe rises and falls, due to the pulsations, the flow through the orifice remains fairly constant and allows the meter to respond to a head corresponding to the average flow.

The vent line from the standpipe leads to the space above the free liquid level in the vessel supplied. Where this is impracticable, the standpipe or chamber may be supplied with compressed air. This method is covered by patents.

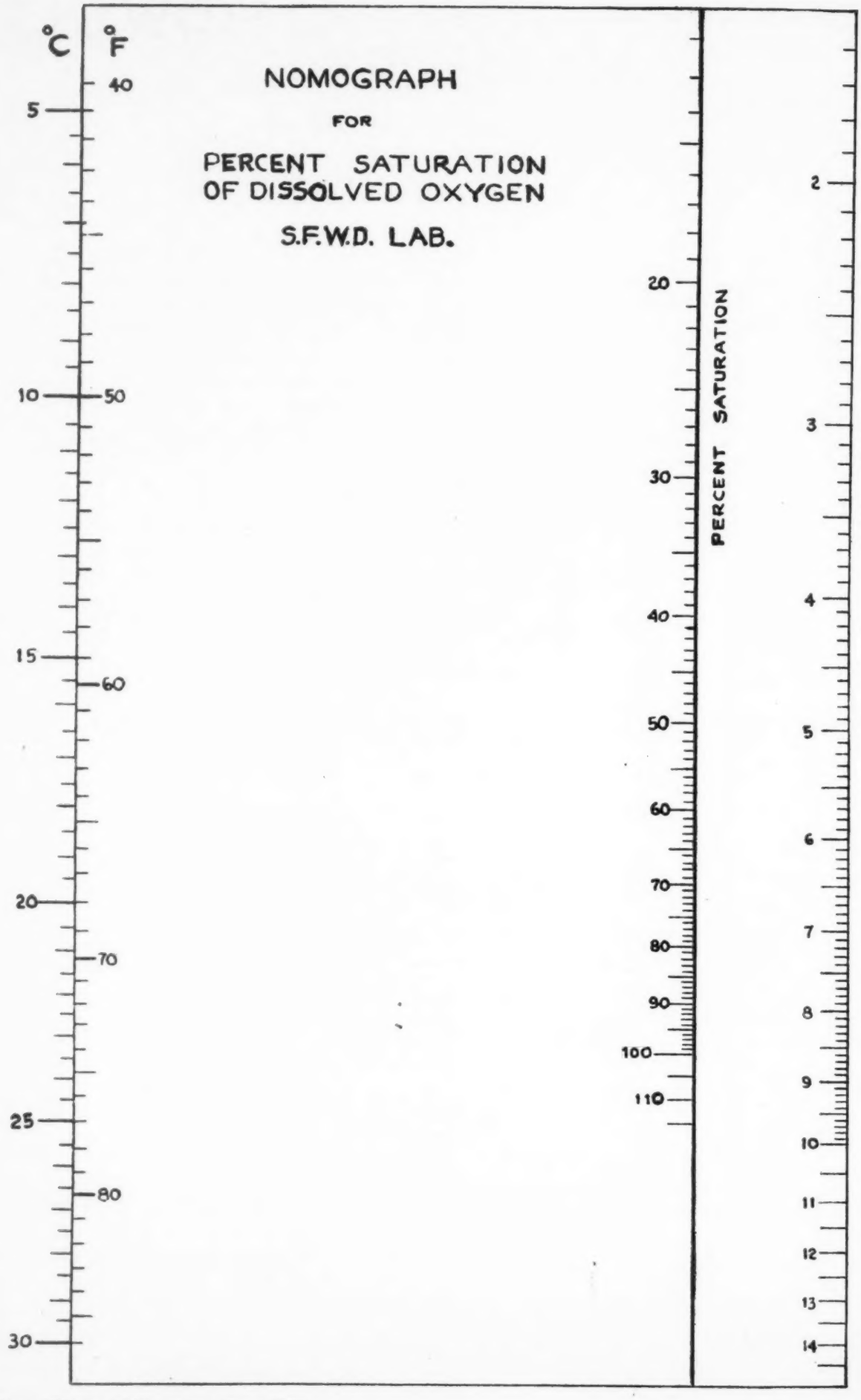
Orifice on Discharge Side of Reciprocating Pumps

When lack of pressure head or other conditions prohibit the orifice being placed on the suction side of a pump, the arrangement illustrated in Fig. 2 can be used. Here the orifice is located on the discharge side.

The water is directed upward into the chamber, where the pulsations cause the compressed air to contract and expand alternately. The pulsations are thus absorbed in the chamber and allow accurate readings to be obtained with the flow meter. This arrangement is also suitable for use in measuring liquids other than water.

Eliminating Pulsations in Steam, Air and Gas

In measuring a compressible fluid such as steam, air or gas, satisfactory results may be attained by installing sufficient receiver capacity and causing the fluid to undergo one or more abrupt velocity changes. This allows the fluid to compress and expand in the receiver space and consequently damps out the pulsations. If a large receiver is not available, "throttling orifices," Fig. 3, may be used to produce changes in velocity. These orifices may be economically constructed of thin sheet metal and inserted between flanges in the line. However, this method results in a pressure loss which is not recoverable, and therefore the use of a receiver may sometimes be preferable. Neither of these last methods is available for measuring water or other liquids, since these fluids are practically incompressible.



This nomograph, developed in the laboratories of the San Francisco Water Dept., has been contributed by G. E. Arnold, Engr. in Charge of Water Purification. Besides saving time and effort in deriving the index of % D. O. Saturation, it reveals the maximum quantity of dissolved oxygen that a water can carry at any given temperature, or pick up by aeration. Also it contains a handy temperature conversion scale.

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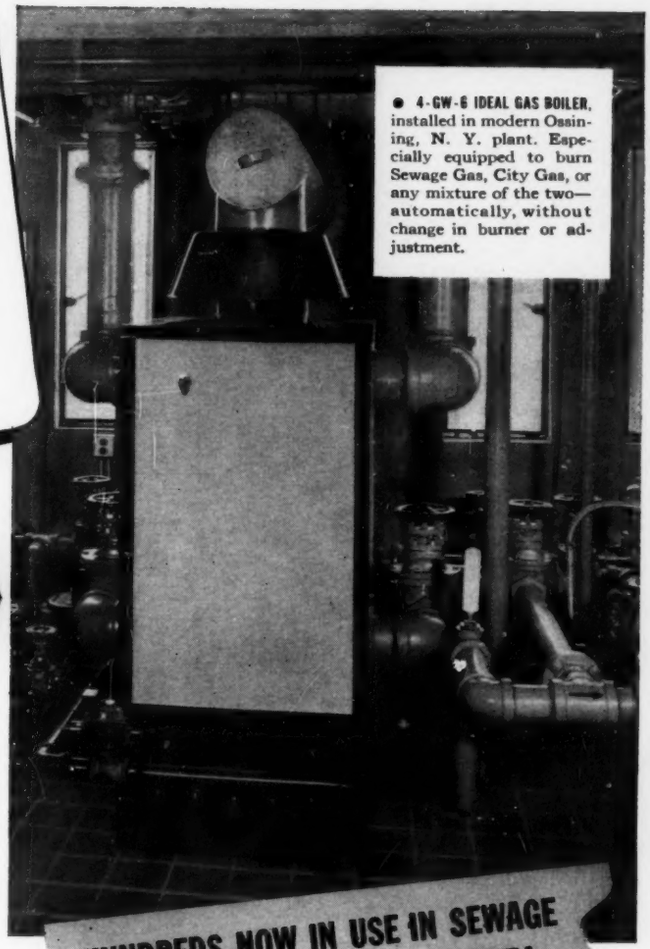

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●If the experience of others is any criterion—it will pay you to specify AMERICAN Gas Boilers for heating your sludge digestion tanks.

These fine Boilers are specifically designed to burn sewage gas efficiently, economically. Completely automatic in operation, one valve controls water temperature to any pre-determined degree. All joints are precision ground iron-to-iron for protection against leakage, and air infiltration. There's a vast range of sizes to meet all requirements exactly. Remember too—AMERICAN GAS-FIRED Automatic Storage Water Heaters keep constant hot water always on tap! Write today for information!

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AMERICAN GAS BOILER CAPACITY WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HR.		BOILER SPACE		
								Floor Space	
Steam	Water	B.T.U. per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	B.T.U. per Hour	Cu.Ft. 700 B.T.U. Sludge Gas	Over-all Hght.	Width Front	Depth
.....	1-GA-4	31,500	.....	210	39,350	56	36¼"	14½"	22½"
.....	1-GA-5	42,000	.....	280	52,500	75	36¼	14½	25½
.....	1-GA-6	52,500	.....	350	65,600	94	36¼	14½	28½
.....	2-GA-4	63,000	.....	420	78,750	113	41¼	19½	22½
.....	2-GA-5	84,000	.....	560	105,000	150	41¼	19½	25½
.....	2-GA-6	105,000	.....	700	131,200	188	41¼	19½	28½
.....	2-GA-7	126,000	.....	840	157,500	225	41¼	19½	31½
.....	4-GA-9	168,000	.....	1120	210,000	300	41½	28	38
.....	4-GA-11	210,000	.....	1400	262,500	375	41½	28	44
.....	4-GA-13	252,000	.....	1680	315,000	450	41½	28	50
0-G8-4E	.....	61,200	255	.....	76,600	109	40½	16	33¾
0-G8-5E	.....	81,600	340	.....	102,000	146	40½	16	37¾
0-G8-6E	.....	102,000	425	.....	127,500	182	40½	16	41¾
0-G8-7E	.....	122,000	510	.....	153,000	218	40½	16	45
1-G8-4	1-GW-4	146,000	610	980	182,500	261	50	35*	33¾
1-G8-5	1-GW-5	186,000	775	1240	232,500	332	52½	39*	33¾
1-G8-6	1-GW-6	225,000	940	1500	281,500	402	53¼	43*	33¾
1-G8-7	1-GW-7	265,000	1105	1770	331,000	473	53¾	47*	33¾
1-G8-8	1-GW-8	305,000	1270	2030	381,000	545	54¾	51*	33¾
1-G8-9	1-GW-9	345,000	1435	2300	431,000	616	57½	55*	33¾
1-G8-10	1-GW-10	384,000	1600	2560	480,000	686	58¼	59*	33¾
1-G8-11	1-GW-11	424,000	1765	2820	530,000	757	58¾	63*	33¾
4-G8-6	4-GW-6	480,000	2000	3200	600,000	857	69	53	52
4-G8-7	4-GW-7	576,000	2400	3840	722,000	1030	69¾	58	52
4-G8-8	4-GW-8	672,000	2800	4480	840,000	1200	71¾	62	52
4-G8-9	4-GW-9	768,000	3200	5120	960,000	1372	72½	66	52
4-G8-10	4-GW-10	864,000	3600	5760	1,079,000	1543	75	70	52
4-G8-11	4-GW-11	960,000	4000	6400	1,200,000	1715	75¾	74	52
4-G8-13	4-GW-13	1,152,000	4800	7680	1,440,000	2060	69¾	85	64
4-G8-15	4-GW-15	1,344,000	5600	8960	1,680,000	2400	71¾	93	64
4-G8-17	4-GW-17	1,536,000	6400	10240	1,920,000	2740	72½	103	64
4-G8-19	4-GW-19	1,728,000	7200	11520	2,162,000	3090	75	107	64
4-G8-21	4-GW-21	1,920,000	8000	12800	2,400,000	3425	75¾	110	64
4-G8-22	4-GW-22	2,016,000	8400	13440	2,520,000	3600	71¾	136	64
4-G8-25	4-GW-25	2,304,000	9600	15360	2,880,000	4120	72½	148	64
4-G8-28	4-GW-28	2,592,000	10800	17280	3,240,000	4625	75	160	64
4-G8-31	4-GW-31	2,880,000	12000	19200	3,600,000	5145	75¾	172	64
4-G8-33	4-GW-33	3,072,000	12800	20480	3,840,000	5480	72½	186	64
4-G8-37	4-GW-37	3,456,000	14400	23040	4,320,000	6165	75	202	64
4-G8-41	4-GW-41	3,840,000	16000	25600	4,800,000	6850	75¾	218	64

1-GS shown. The 1-GW is 4" shorter.

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AMERICAN GAS-FIRED STORAGE WATER HEATERS

Water Heater No.	Name and Type	Size Gal.	B.T.U. Input	Recov.* Gal. Per Hour
154-S	Budget-Steel Tank	15	16,000	22.4
204-S	" " "	20	20,000	28.0
304-S	" " "	30	24,000	33.6
404-S	" " "	40	30,000	42.0
203-S	Clipper-Steel Tank	20	20,000	28.0
303-S	" " "	30	30,000	42.0
403-S	" " "	40	30,000	42.0
603-S	" " "	60	45,000	63.0
755-S	" " "	75	45,000	63.0
205-C	Decatur-Strengthened Copper Tank	20	19,000	26.6
305-C	" " " "	30	24,000	33.6
405-C	" " " "	40	30,000	42.0
755-C	" " " "	75	45,000	63.0

*U. S. Gallons raised 60F. Recovery capacity Imperial Gallons = U. S. Gallons ÷ 1.2

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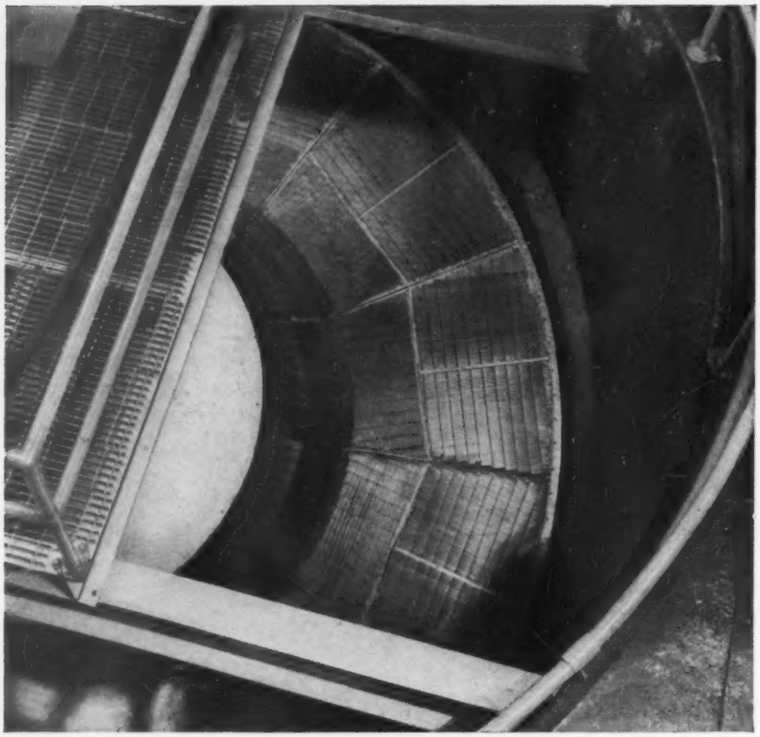


Everdur copper-silicon alloy screens in the Congress Street Plant of Bridgeport, Connecticut, Sewage Disposal System.

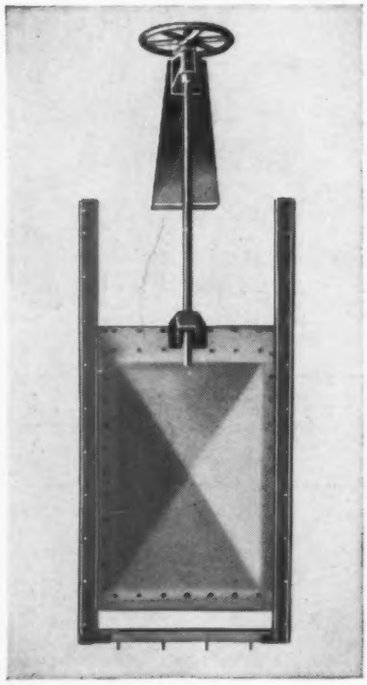
Everdur

THE METAL OF MANY USES IN SEWAGE TREATMENT

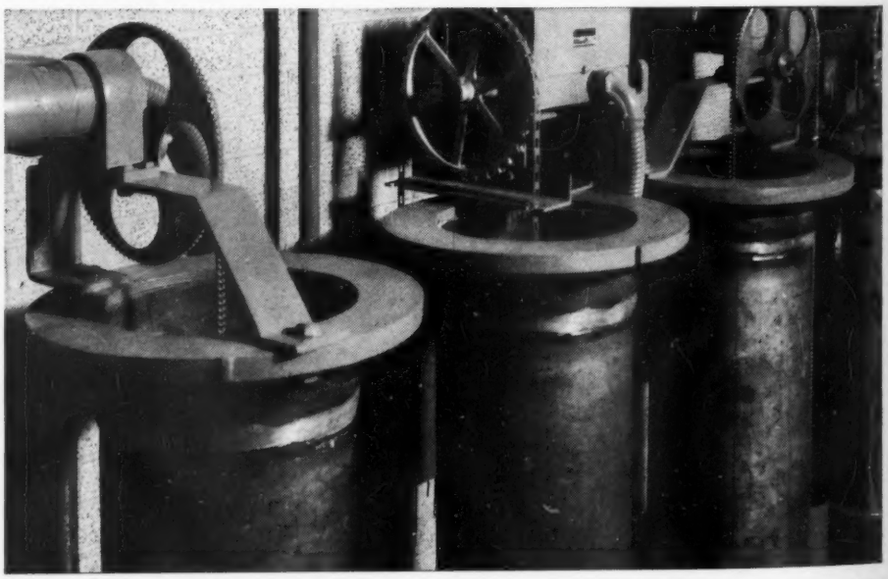
•

Right down the line from huge screen plates to the smallest bolt, Everdur is being specified on its remarkable qualifications for use in sewage treatment plants. These qualifications include high corrosion resistance, high strength, ease of fabrication and ready weldability.

Throughout a fourteen-year period, this moderately-priced copper-silicon alloy has proven its superiority for sewage treatment equipment under a wide variety of operating conditions. So, perhaps Everdur can help you solve *your* problem. In any case, you'll find it well worth while to write for Anaconda Publication E-11. It gives detailed information on Everdur's applications in the sewage treatment field.



One of the five easily hand-operated Everdur shut-off gates in the screen room of the Rahway Valley Joint Meeting Sewage Treatment Works, Rahway, N. J. The frame is cast Everdur, the plate is rolled Everdur, the 2½" spindle is machined Everdur rod. Height of frame —10' 3"; total weight only 1,624 lbs.



Control mechanism of 12" diameter Everdur float tubes. Designed and built by Krajewski-Pesant Mfg. Corp., for the Ward's Island Sewage Treatment Works of the City of New York. In the air filters in both primary and secondary rooms at Ward's Island, entire filter structures, filter holders, retaining mesh and rotating screen were made of Everdur by the American Air Filter Co., Inc., Louisville, Ky. 4110

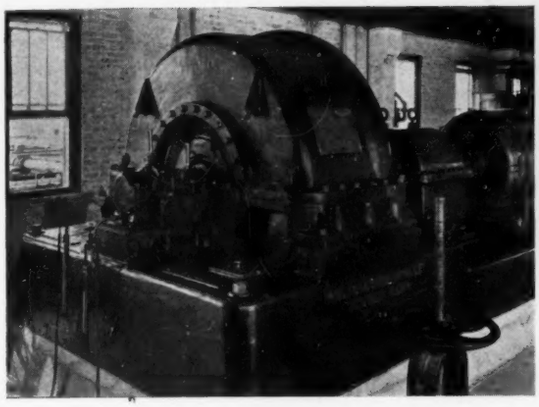
ANACONDA **Everdur Metal**

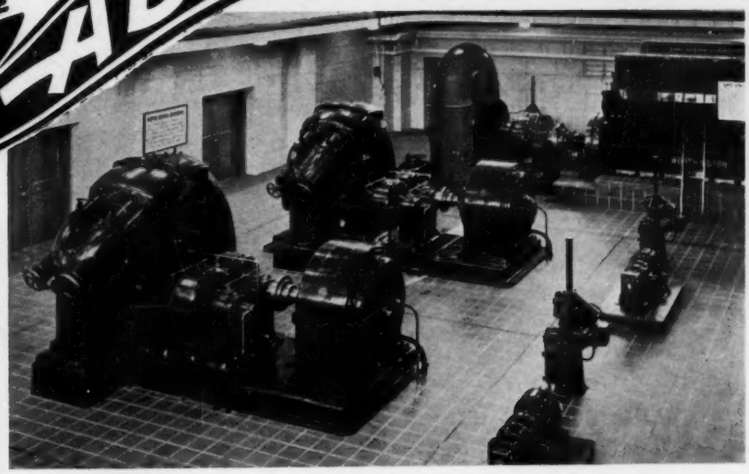
THE AMERICAN BRASS COMPANY, General Offices: WATERBURY, CONNECTICUT

Subsidiary of Anaconda Copper Mining Company • In Canada: ANACONDA AMERICAN BRASS LTD., New Toronto, Ont.

EVERDUR is a trademark of The American Brass Company, registered in the United States Patent Office.

ASK— Roots CONNERSVILLE —ABOUT—



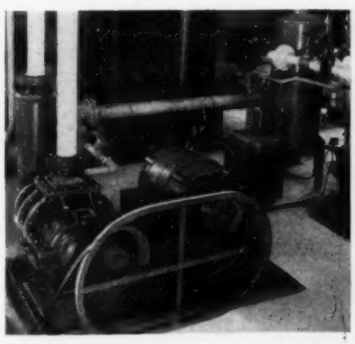


Air FOR WATER AND SEWAGE TREATMENT

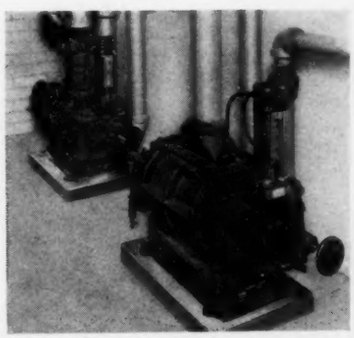
First hand experience in building hundreds of blowers for some of the largest municipal sewage and water treatment plants as well as for smaller communities has given this organization an intimate understanding of the problems involved in the application of air for this purpose. This knowledge may be of use to you when you are planning aeration for any size plant. It is freely at your disposal.

The Roots-Connersville Centrifugal Blower shown at left above is installed at Houston, Texas, capacity 13,500 CFM against 6 lbs. pressure. Illustrated at upper right are three Positive Displacement Blowers installed at Fort Wayne, Indiana. Two motor driven units have a capacity of 7000 CFM each at 7¾ lbs. and the third blower in the background is driven from gas engine, showing a big saving in power cost. Capacity, 11,000 CFM at 7¾ lbs.

Vacuum FOR YOUR FILTERS



The same rugged simplicity that makes "R-C" Rotary Positive Blowers so free from maintenance is found in the "R-C" Positive Displacement Vacuum Pump. Pumps like this one at Washington, D. C., keep sludge dewatering filters working at maximum efficiency. Built in a wide range of sizes, vacuum to 25" Hg.



Metering OF SLUDGE GAS

Accurate metering of sludge gas is simple and inexpensive with Connersville Rotary Displacement Meters. Pressure absorption is low—normally about ½" water column. Accurate over a range of from 5% to 150% of rated capacity. Registers direct in cu. ft. without calculation. Meters shown are at Richmond, Indiana.

IN HANDLING AIR AND GAS Experience Counts

ROOTS-CONNERSVILLE BLOWER CORP.

107 Mount Avenue **CONNERSVILLE, IND.**

NEW YORK CHICAGO POTTSTOWN, PA SAN FRANCISCO PITTSBURGH BOSTON DETROIT ST. LOUIS LOS ANGELES

17109

Greeley and Hansen, Engineers — O. F. Schoeptle, Filtration Engineer
Installed by Roberts Filter Mfg. Co.

OMEGA FEEDERS

at Sandusky, Ohio

These feeders have stainless steel feeding mechanisms with totalizers showing total pounds fed.

The accuracy on five minute tests for average rates and conditions will be within 1% and in many cases within 1/4 of 1% under regular working conditions.

There are two similar feeders for carbon in a separate room.

Write us for full particulars and your problems.

OMEGA MACHINE COMPANY

4010 PENN — KANSAS CITY, MO.

CHAMPION CORPORATION 4714 Sheffield Ave. HAMMOND, IND.

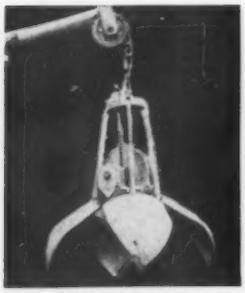
TWIN RIG. OK Champion Power Sewer Cleaner is the only equipment that removes debris from sewer to street level in ONE operation.

Announces

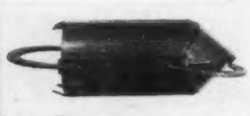
DOUBLE-DUTY CLEANER *for* SEWERS *and* CATCH BASINS

New Combination Equipment Speeds-Up Work Cuts Cost of Restoring Sewerage Efficiency

Now! . . . A new combination of equipment that cleans BOTH Catch Basins and Sewers—quickly. Make sewer and catch-basin cleaning routine operations and maintain your sewerage system at 100% operating capacity.



FOR CATCH BASINS. Orange Peel bucket operates through man-hole opening. A tremendous time-saver over old hand-shovel methods.



FOR SEWERS. Traveling expansion bucket bites into blockade; closes on reverse pull, withdraws to street level, empties automatically—all in a continuous mechanical operation.

Saves Its Cost — QUICK!

Tree roots, sand, gravel, and other heavy debris decrease and eventually stop sewage flow. Damage from this clogging can be avoided by a small precautionary investment—averaging only 3½c to 7c per foot—in the seasonal renovation of your sewage system. These low costs are possible only with this easily interchangeable equipment—powered by the OK Champion Twin or Single Rig Power Cleaner. **Write for Free Literature.**

Highway culverts also easily cleaned with OK Champion Tools — Write us.

Ask Abut Our 10-DAY FREE TRIAL

O.K. Champion — HAMMOND, INDIANA

CHAMPION CORPORATION, 4714 Sheffield Ave., HAMMOND, IND.

MEETINGS SCHEDULED

June 22-26—TORONTO, ONT. (Royal York Hotel)
American Water Works Association. Annual Convention. Secretary, Harry E. Jordan, 22 E. 40th St., New York, N. Y.

June 22-26—TORONTO, ONT. (Royal York Hotel)
Canadian Section A.W.W.A. (Annual Meeting). Secretary, A. E. Berry, Ontario Department of Health, Parliament Building, Toronto, Ont. (Meeting Jointly with Annual Convention of A.W.W.A.)

Aug. 7-9—ERIE, PA. (Lawrence Hotel)
Western Penna. Section A.W.W.A. Secretary, E. P. Johnson, 418 Flannery Bldg., Sta. 13, Pittsburgh, Pa.

Sept. 1-3—STATE COLLEGE, PA. (Pa. State College)
Pennsylvania Water Works Operators' Association. Sec'y Treas., I. M. Glace, 22 South 22nd Street, Harrisburg, Pa.

Sept. 3-5—STATE COLLEGE, PA. (Pa. State College)
Pennsylvania Sewage Works Association. Sec'y-Treas., Bernard S. Bush, Kirby Health Center, Wilkes-Barre, Pa.

Sept. 11-12—GLENS FALLS, *N. Y.* (Hotel Queensbury).
New York Section A.W.W.A. (Fall Meeting). Secy-Treas., R. K. Blanchard, Neptune Meter Co., 50 West 50th St., New York, N. Y.

Sept. 18-19—SANTE FE, NEW MEXICO (LaFonda Hotel)
Rocky Mountain Section A.W.W.A. Secretary, E. V. Howe, Sanitary Engineer, State Board of Health, Denver, Colo.

Sept. 19-20—PROVIDENCE, R. I. (Hotel Biltmore).
New England Sewage Works Association. (Annual Fall Meeting.) Sec'y-Treas., LeRoy W. VanKleeck, State Dept. of Health, Hartford, Conn.

Sept. 23-26—BOSTON, MASS. (Hotel Statler)
New England Water Works Association (Annual Convention). Secretary, Frank J. Gifford, 613 Statler Building, Boston, Mass.

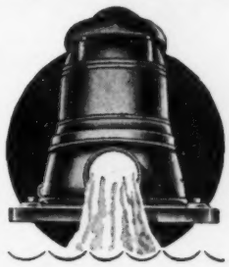
Sept. 24-26—GRAND RAPIDS, MICH. (Hotel Pantlind)
Michigan Section A.W.W.A. Secretary, Maurice N. Gerardy, Department of Water Supply, Detroit, Michigan.

Oct. 6-8—RACINE, WIS. (Hotel Racine)
Wisconsin Section A.W.W.A. Sec'y-Treas., Leon A. Smith, City Hall, Madison, Wis.

Oct. 9-11—MINNEAPOLIS, MINN. (Nicollet Hotel)
Minnesota Section A.W.W.A. Secretary, R. M. Finch, Wallace & Tiernan Co., Inc., 416 Flour Exchange, Minneapolis, Minn.

Oct. 9-11—NEW YORK, N. Y. (Hotel Pennsylvania)
Federation of Sewage Works Associations. Executive Secretary, W. H. Wisely, P. O. Box 18, Urbana, Ill.

WATER FOR THIS BIG PAPER MILL



DOWN at Lufkin, Texas, stands the great Southland Paper Mills—the first to be erected for making newsprint from Southern yellow pine. Typical with the great majority of paper mills, Layne Wells and Pumps were selected to supply their water. A battery of five high efficiency units provide the Southland Mills with over 10,000,000 gallons daily.

Not only will you find Layne Wells and Pumps serving paper mills, but check also with cities, towns, communities, defense plants, army camps, air fields, railroads, packing houses, breweries, chemical plants and an almost unlimited variety of industries. There you will find Layne Wells and Pumps in operation.

Layne Wells and Pumps are entirely designed, built and installed by the Layne organization. They invariably give longer years of service and break all records of low upkeep expense. For latest bulletins, catalogs, etc., without obligation, address

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LAYNE-ARKANSAS CO. STUTTGART, ARK.
LAYNE-ATLANTIC CO. . . . NORFOLK, VA.
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LAYNE-NEW YORK CO. . NEW YORK CITY AND PITTSBURGH . . . . . PA.
LAYNE-NORTHWEST CO. MILWAUKEE, WIS.
LAYNE-OHIO CO. . . . COLUMBUS, OHIO
LAYNE-TEXAS CO. . . . HOUSTON AND DALLAS . . . . . TEXAS.
LAYNE-WESTERN CO., KANSAS CITY, MO. CHICAGO, ILL. . . . OMAHA, NEBRASKA
LAYNE-WESTERN CO. OF MINNESOTA MINNEAPOLIS . . . . . MINN.
LAYNE-BOWLER NEW ENGLAND COMPANY, BOSTON . . . . . MASSACHUSETTS.
INTERNATIONAL WATER SUPPLY, LTD., LONDON . . . . . ONTARIO, CANADA

LAYNE & BOWLER, INC.
Memphis, Tenn.

LAYNE

PUMPS & WELL WATER SYSTEMS
For Municipalities, Industries, Railroads, Mines and Irrigation

We use A FEW BILLION GALLONS OF WATER OURSELVES . . .

As you will note by the little "Anchor" seal, this is Solvay's 60th Anniversary. That means that in 60 years we have had to find out a whole lot about water and its characteristics . . . for the very plain reason that our own manufacturing processes require the use of millions of gallons yearly.

Our business also takes us into many manufacturing fields where the relation between water and alkalies is extremely important to manufacturers' processes. We make, for instance, cleansers of various types for a variety of industries, which, in itself, requires a broad knowledge and experience of water conditions in every section of the country.

As manufacturers of Liquid Chlorine and Alkalies, used in both municipal and industrial water treatment, we have for years been in direct contact with water treating problems.

Much of this accumulated experience in the field of water treating can be yours merely for the asking. And with such a background, we do not feel it too much to say that water treating problems, whatever their nature, are "right down the alley" of Solvay Technical Service. Your inquiries are cordially solicited.

SOLVAY SALES CORPORATION

Alkalies and Chemical Products Manufactured by The Solvay Process Company

40 RECTOR STREET NEW YORK, N. Y.

BRANCH SALES OFFICES:

Boston • Charlotte • Chicago • Cincinnati • Cleveland • Detroit
New Orleans • New York • Philadelphia • Pittsburgh • St. Louis • Syracuse

Plants Located At:

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SOLVAY

TRADE MARK REG. U. S. PAT. OFF.

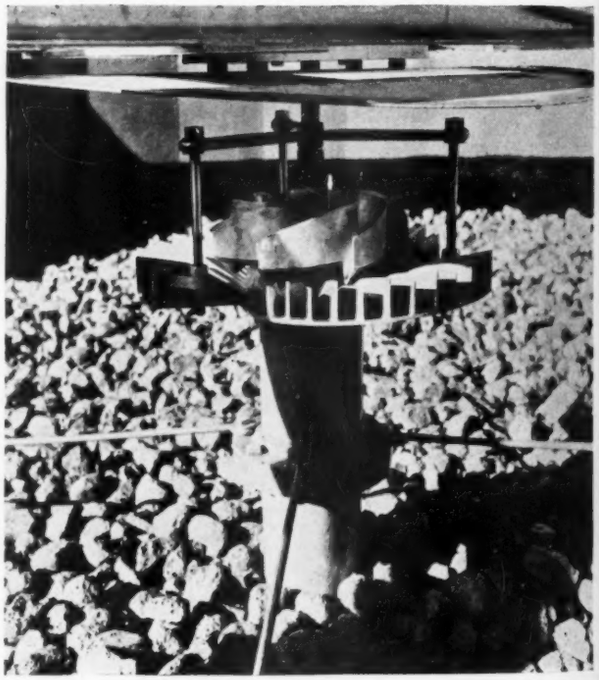
TECHNICAL SERVICE

The AERO-FILTER

LOW Installation Cost and Operating Cost

The unvarying success, low first cost, low operating cost, flexibility to meet local conditions to insure application on the entire filter surface for each revolution of the distributor, minimum clogging trouble, has won for AERO-FILTER wide favorable recognition in the sewage treatment field.

Ask for information and cost data sheets . . . compare AERO-FILTER low initial and operating costs, satisfy yourself as to the flexibility of AERO-FILTER to meet YOUR sewage problem.



There are now more than fifty-five installations in twenty states.

LAKESIDE ENGINEERING CORPORATION

222 W. Adams St. Chicago, Ill.

MEETINGS SCHEDULED

Oct. 13-16—FORT WORTH, TEXAS
Southwest Section A.W.W.A. Secretary, L. A. Quigley, Supt. City Water Works, Fort Worth, Texas.

Oct. 13-17—ATLANTIC CITY, N. J. (Hotel Traymore)
American Public Health Association. Exec.-Sec'y, Reginald M. Atwater, Md., 1790 Broadway, New York, N. Y.

Oct. 14-17—ATLANTIC CITY, N. J. (Convention Hall)
American Public Health Association (70th Annual Meeting). Executive-Secretary, Reginald M. Atwater, M.D., American Public Health Ass'n., 1790 Broadway, New York, N. Y.

Oct. 15-17—ATLANTIC CITY, N. J. (Haddon Hall)
Pennsylvania Water Works Association. Secretary, Dr. F. Herbert Snow, 710 Telegraph Bldg., Harrisburg, Pa.

Oct. 16-18—ATLANTIC CITY, N. J.
New Jersey Section A.W.W.A. Secretary, C. B. Tygert, P. O. Box 187, Newark, N. J.

Oct. 19-22—NEW ORLEANS, LA.
American Public Works Association. Executive Director, Norman Hebden, 1313 East 60th St., Chicago, Ill.

Oct. 20-22—CEDAR RAPIDS, IOWA (Montrose Hotel)
Missouri Valley Section A.W.W.A. Secretary, Earl L. Waterman, Prof. of Sanitary Engineering, Univ. of Iowa, Iowa City, Ia.

Oct. 22-25—FRESNO, CALIF. (Hotel Fresno)
California Section A.W.W.A. Sec'y-Treas., G. E. Arnold, San Francisco Water Department, Millbrae, Calif.

Oct. 27-29—NASHVILLE, TENN. (Andrew Jackson Hotel)
Kentucky-Tennessee SECTION A.W.W.A. Secretary, H. D. Schmidt, Director Div. of Sanitary Engineering, Department of Health, Nashville, Tenn.

Nov. 3-5—HIGH POINT, N. C. (Sheraton Hotel)
North Carolina Section A.W.W.A. and
North Carolina Sewage Works Association. Secretary, R. S. Phillips, Box 1170, Durham, N. C.

Nov. 6-7—BALTIMORE, MD.
Four States Section A.W.W.A. Secretary, Lloyd Nelson, U. S. Pipe and Foundry, Broad and Chestnut Streets, Philadelphia, Pa.

ACCURACY and DURABILITY since 1855

The first Water Meter patent in the United States was granted to Henry R. Worthington in 1855 . . .

As a result of continuous development by expert water works engineers, coupled with the finest manufacturing facilities, Worthington-Gamon is today supplying Corporate and Private interests with the most accurate and dependable liquid meters.

Upon your request, the nearest Worthington-Gamon office will furnish you with descriptive literature covering the many modern features of Watch Dog Meters.

WORTHINGTON-GAMON METER COMPANY
General Offices: HARRISON, NEW JERSEY
Offices and Representatives in Principal Cities

WORTHINGTON-GAMON

WG1-4A

Handle Chemicals Cheaper *and* Better

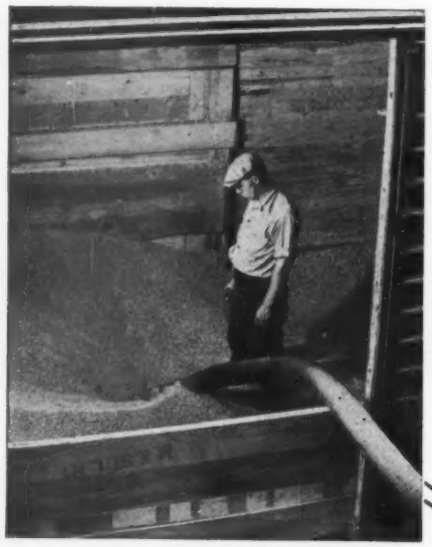
by the MODERN

DRACCO Pneumatic Conveyor Way

The following Chemicals are efficiently and economically handled by DRACCO Pneumatic Conveyors in Water Works and Sewage Treatment Plants located in all parts of the country. Alum, lime, soda ash, bauxite, ferrous sulphate, pebble lime, activated carbon, and ammonium sulphate.

A PARTIAL LIST OF *DRACCO* INSTALLATIONS

FRIDLEY FILTRATION PLANT	Minneapolis, Minn.
DALECARLIA FILTRATION PLANT	Washington, D. C.
MUNICIPAL WATER SOFTENING PLANT	Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT	Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT	Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT	Niles, Ohio
MUNICIPAL WATER PLANT	Columbus, Ohio
MUNICIPAL WATER PLANT	Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT	Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT	Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT	Dallas, Texas
MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
MINNEAPOLIS-SAINT PAUL SANITARY DISTRICT (Sewage Disposal Plant, 2 installations)	St. Paul, Minn.
MUNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT	Denver, Colorado
MUNICIPAL WATER PLANT	Covington, Ky.
MUNICIPAL WATER PLANT	Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT	Atlanta, Ga.
SEWAGE DISPOSAL PLANT (2 installations)	Cleveland, Ohio
MUNICIPAL WATER PLANT	Benton Harbor, Mich.
MUNICIPAL WATER PLANT	Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT	Detroit, Mich
MUNICIPAL WATER PLANT	Flint, Mich.
CITY OF TORONTO WATER WORKS PLANT	Toronto, Ontario
WATER FILTRATION PLANT	Ottawa, Kansas
EL RENO WATER TREATMENT PLANT	El Reno, Oklahoma
CITY OF GRAND FORKS	Grand Forks, North Dakota
MUNICIPAL SEWAGE PLANT	Pittsburgh, Pennsylvania
WATER FILTRATION PLANT	Wichita, Kansas



Write for Bulletin No. 526

• For Further Information Write •

DRACCO CORPORATION

Successors to The Dust Recovering & Conveying Co.

4079 E. 116th St., Cleveland, O. • New York Office, 130 W. 42nd St.

PNEUMATIC CONVEYORS • DUST COLLECTORS

ferri-floc

FERRIC SULPHATE

will save you money

on

WATER TREATMENT

SEWAGE TREATMENT

and

SLUDGE CONDITIONING

FERRI-FLOC, the coagulant for all types of water and sewage treatment. Results show large savings in cost of coagulation. ferri-floc is widely used to condition sludge for vacuum filtration or drying bed disposal. It lowers the cost and is less trouble to store and feed.

FOR ALGAE CONTROL

Tennessee

99% COPPER SULPHATE

Controls Mico-organisms in reservoirs and filter plants. In bbls. or 100-lb. bags. Sizes for various type feeders.

Write for **FREE BULLETINS** *and* **SAMPLES**

Tennessee Corporation

ATLANTA, GA. • LOCKLAND, OHIO

LITERATURE AND CATALOGS

"Clamp Down" is the theme of a folder from W. & T. Co., which warns operators and engineers that now is the time to be preparing to clamp down on the summer odor nuisance from sewage plants and pumpstations. The folder provides evidence in the way of numbers of installations and performance records to show that pre-chlorination "clamper-downer" on seasonal sewage odors. If you would like to learn more concerning "Preservative Chlorination," nothing more is needed than a post-card addressed to Wallace & Tiernan Co., P. O. Box 178, Newark, N. J.

Centrifugals, by Gardner-Denver, for pumping sewages and wastes are described and pictured in a new Gardner-Denver Bulletin, which does the job of showing the reader what the Type J. horizontal and Type K. vertical pumps are like inside. Typical specifications are given and dimensions are tabulated. Anyone not familiar with Gardner-Denver pumps should have a copy of this bulletin A-304. Write Gardner-Denver Co., Quincy, Ill.

"The What, How and Why of the Accelator" is the caption on a new brochure from International Filter Co., which is rather self-explanatory. In the foreword it is explained that the article reprinted is designed to answer several important questions as to "why the Accelator has many exclusive advantages in clarification, softening and stabilizing waters." This the article does very effectively, including the presentation of operating data from 20 representative installations. For a copy of Bul. 1824 write International Filter Co., 325 W. 25th Place, Chicago.

"Patching and Waterproofing Cements," bearing the trade name "Smooth-on," are described in a recently issued leaflet, which describes the products and pictures their applications in patching or waterproofing concrete walls and floors. It shows how leakage or seepage can be stopped from the outside of tanks, basins, etc., or the inside of cellars, cisterns, etc. So many operators have need for such a cement, judging from requests for information, we would recommend writing for the "Smooth-on" literature. Address Smooth-On Mfg. Co., Dept. 393, 570 Communipaw Ave., Jersey City, N. J.

"Grounds Maintenance" is the caption of an interesting little booklet of 48 pages from the C. B. Dolge Co. of Westport, Conn. This manual, in alphabetical order, describes and pictures the many pests that ruin nice lawns, shrubbery, etc., and presents the modern methods for their eradication or control. The manual covers insects, worms, fungi, and weeds that grow in water as well as on land. An interesting piece of control equipment is the "Hpocane," which is used for hypodermizing those hard-to-get pests, such as dandelion, plantains, etc., with Dolge weed-killer. The manual contains many helpful hints on "Grounds Maintenance" and useful information concerning sprays and other control measures. For a copy, address the C. B. Dolge Co., Westport, Conn.

Oakite Compd. No. 32 is described in a booklet from Oakite Products, Inc., which tells of the value of this special compound as a remover of hard water scab or rust deposits from pipe systems, water meters, cooling systems of engines, etc. One page is devoted to the effectiveness of Oakite Compd. 32 in renovating

(*Continued on page* 107)

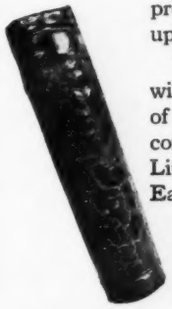
FOR EFFECTIVE PIPE PROTECTION

COATINGS must be WRAPPED with ASBESTOS FELTS

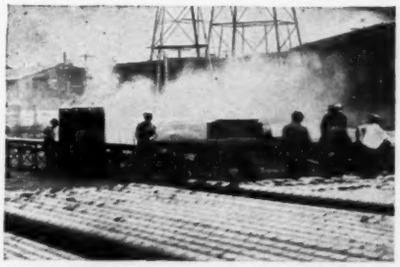
● Here's a money-saving tip to waterworks engineers. More than 25 years' experience in the oil and gas industries has proved many types of ferrous pipes must be protected by a corrosion-resistant coating. What's more, the coating must be reinforced or shielded with a strong, durable wrapping to prevent distortion and abrasion. And, for that service, asbestos—in the form of J-M Pipe-Line Felts—has proved the ideal material.

Because the asbestos fibers are inorganic and non-tubular, J-M Asbestos Felt cannot support capillary action. Tough and durable, it reinforces the coating against earth load and soil stress. And, because it is exceptionally resistant to the corrosive action of soil acids and alkalis, this durable felt gives efficient protection for the coating . . . helps keep upkeep costs to a minimum.

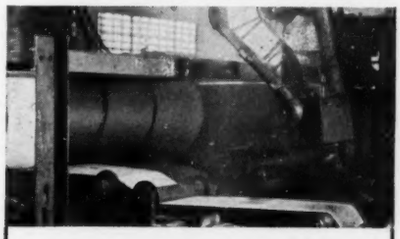
You'll be interested in the whole story. It will show you why more than 30,000 miles of pipe are operating at low cost under severe conditions. Write for the J-M Asbestos Pipe-Line Felt brochure to Johns-Manville, 22 East 40th Street, New York, N. Y.



UNWRAPPED BITUMINOUS COATING after exposure to clay-content soil. Soil stress has destroyed much of the protective coating.



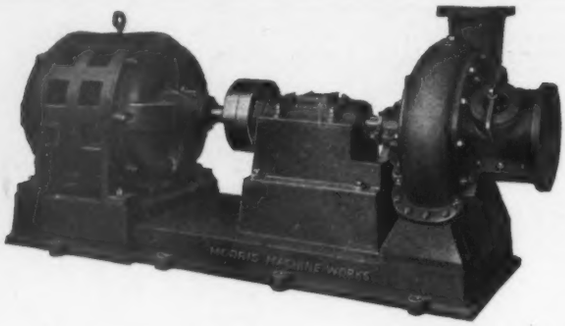
THE SAME COATING, under the same conditions, but wrapped with J-M Asbestos Felt. The wrapping shows no signs of breakdown . . . the coating underneath is practically as good as new.



YOU CAN PURCHASE pipe from the steel-pipe mill coated with any standard coating material and wrapped with Johns-Manville Asbestos Felts. Or the same operation can be performed in your own yard by portable wrapping equipment supplied on a rental basis. Write Johns-Manville, 22 East 40th Street, New York, N. Y., for further information.

JOHNS-MANVILLE JM PRODUCTS

ASBESTOS PIPE-LINE FELTS



An unpleasant duty?

Handling sewage is an undesirable job, but not to a Morris Non-clogging Pump. These omnivorous units will take care of anything that might come their way—pulp, debris, trash, even pieces of wood and clothing. Moreover, they do their work with remarkably high efficiencies and seldom require attention of any kind. For full information on pumps that handle sewage as if they liked it, write for Bulletins 160 and 161.

MORRIS MACHINE WORKS . . BALDWINSVILLE, N. Y.

MORRIS
CENTRIFUGAL PUMPS

"PERMANENT CARRYING CAPACITY"

MONO-CAST
ENAMELINE
CAST IRON PIPE & FITTINGS

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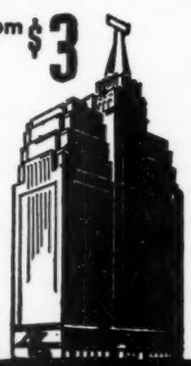

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water meters, and curves are given to show how gentle the compound is on metal parts while loosening the adhering scale or rust. For a copy, write Oakite Products, Inc., 22 Thames St., New York.

The Story of Bitumastic in a Filter Plant is told in this month's "Bitumastic Bulletin," published by Wailes-Dove Hermiston Corpn. of Westfield, N. J. Another story is that of the reclamation, cleaning and lining of old 6" and 12" pipes at Spartanburg, S. C., with hot Bitumastic 70-B. spun on—the work all being done by Water Dept. employees. Another interesting story in the same issue is that reporting on the excellent condition of the Bitumastic Enamel applied to 36" pipes crossing under the Narrows of N. Y. Harbor some 25 years ago.

This **F. M. Likes Biofiltration,** is very apparent in the "F.M. News" for May and June. The story at point refers to the number of installations of the Biofiltration Process and the extensive use of F.M. Vertical Propeller Pumps which are ideally suited to lifting large volumes against low heads, netting about 80% efficiency. The Biofiltration Process is pretty well described. On the page following is pictured a room full of F.M. motors in the new South St. Paul Sewage Treatment Plant. If you do not receive "F.M. News," issued every second month, possibly you would like it. Address Fairbanks-Morse & Co., 600 So. Michigan Blvd., Chicago.

How to Start and Protect Synchronous Motors for best results, is a G.E. presentation of "Four little known facts" concerning synchronous motors and their operation. For a copy of Folder GES-2677, write General Electric, Schenectady, N. Y.

Aqua Ammoniation in the ammonia-chlorine process is the subject of a special folder from %Proportioneers Inc.% of Providence. The article by H. N. Armbrust discusses the value of "Chloramination" and, in particular, the advantages of applying the ammonia in solution as ammonia water, rather than gaseous form, and lists a number of plants where Aqua-Ammoniation is now practiced. "Amm-O-Feeders" are pictured and typical installations sketched, the most important being that at the Washingon Filter Plant. A compact self contained feeder and solution reservoir is "The Packaged Amm-O-Feeder," especially and inexpensively designed for small plants. For a copy of "Chloramination of Water," by H. N. Armbrust, write %Proportioneers Inc.%, 9 Codding St., Providence, R. I.

F-M Submerged Suspended Pumps, especially designed for sump and bilge duty, are presented in a recent Fairbanks Morse bulletin. Details and features of construction of these non-clog enclosed impeller type pumps are illustrated in a cut-away view. Emphasis is placed on the fact that the F-M motor and F-M pump performance come under a single guarantee by one manufacturer who furnishes the complete unit. Specifications and a useful pump selection guide table completes Bulletin 5410 SS. For a copy, write Fairbanks, Morse & Co., 600 Michigan Blvd., Chicago, Ill.

"Radio Equipment" is the subject of literature recently received from Technical Radio, Inc., of San Francisco, will interest any who are contemplating equipping trucks, service cars or stations with radio equipment. The "Radio Sentinel" is described as a recording and transmitting unit for reservoirs,

(*Continued on page* 110)

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Gas Engines by Worthington are subject of a new bulletin devoted to type EEG Worthington engines especially suitable for operating at sewage treatment plants on digester gas. Illustrations and specifications of pictured parts tell the story in a complete manner. Installation pictures include the largest to date in America—that of the Tallmans Island Sewage Works of New York City, where the engines are direct connected to air blowers and sewage pumps. Incidentally all but a fraction of the total power requirement at this particular plant is now being developed from gas. Roughly 10 per cent of the total gas requirement is being taken from the system of the local gas utility, this quantity gradually reducing with the trend in improved operating efficiencies. For a copy of Bul. S-550—B-15 write Worthington Pump and Machinery Corp., Harrison, N. J.

"Instrumentation of Sewage Works," by Foxboro is a bulletin which does a splendid job of setting forth the advantages of proper instrumentation of modern sewage treatment plants, leading to efficient operation and permitting the many advantages of centralized control. It is illustrated with a typical plant portrayed by isometric drawings and each point marked at which Foxboro Instrumentation has advantages. Then follows details and picturization of the several Foxboro instruments applicable to the various operations and all leading to Centralized Control. Convenient Foxboro Service is revealed in a listing of the number of well distributed branch offices of the company. For a copy of Bulletin 232, write The Foxboro Co., Foxboro, Mass.

"Roots — Connersville Blowers" are subject of a new folder of 8 pages which covers briefly the applications of the complete line of Roots-Connersville products. The folder is profusely illustrated with installation views, but text matter has been minimized. Separate pages are devoted to positive displacement blowers, positive gas exhausters and boosters, rotary displacement meters, liquid and vacuum pumps, centrifugal blowers and exhausters, and inert gas generators, while on the back page appears a brief summary of the applications for which each type of equipment is suited, together with a list of more detailed bulletins available. A copy of Bulletin G-70 may be had by addressing the Roots-Connersville Blower Corp., Connersville, Ind.

Anderson Valves are presented in a 53 page 5½ x 8½" catalog, with flexible binding of the ring type, from Anderson Valve Corp. of Pittsburg, specialists for a number of years in the production of various automatic valves for water and sewage works. Specifications, illustrations and typical installation sketches are given for a variety of automatic altitude control valves, simple float valves, automatic pressure reducing and pressure control valves, remote control valves, cone type valves, pressure relief valves, etc. Featured is the Air Cushioned Double Acting principle in Anderson Automatic Valves for altitude and pressure control. For a copy of Catalog No. 55 write Anderson Valve Corp., American Bank Bldg., Pittsburgh, Pa.

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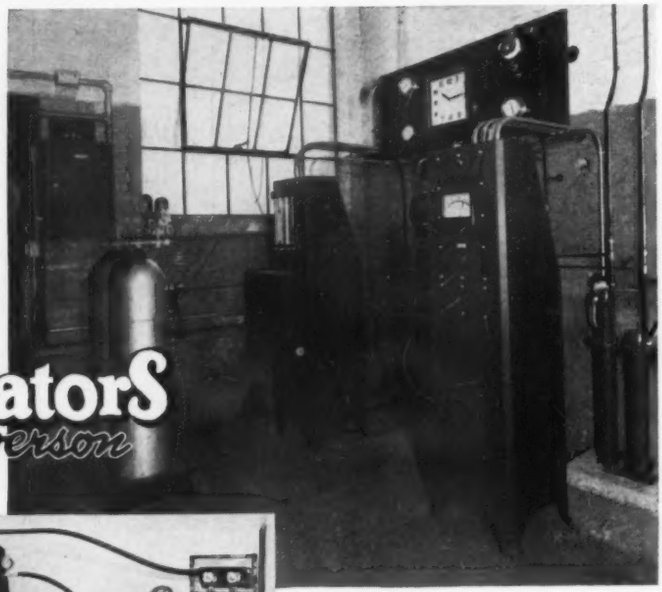

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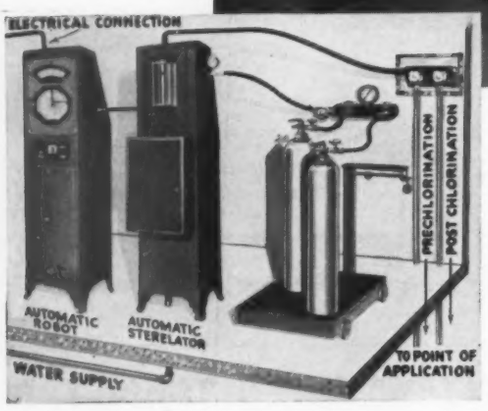

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"Worthington Pressure Filters and Softeners" are the subject of two separate bulletins devoted to pressure filters and hot water softeners. Fetaures of Worthington Pressure Filters are emphasized by word and picture, and tables of capacities, dimensions and weights of filters are given; also representative installation views. The Softener Bulletin describes the equipment and hot softening process. For Bulletin W-210-B26 (Filters) or W-210-B27 (Softeners) write Worthington Pump and Machinery Corpn., Harrison, N. J.

"Bardco Portable Generators" are presented in a new bulletin from Bardco of Los Angeles and Dayton, Ohio. The brochure announces the addition of seven air-cooled small sized portable generators to the Bardco line and ten water cooled enclosed models. Outputs of the air cooled models are 500, 1,000, 1,500 and 2,000 watts at 6, 12, 32 or 110 volts D.C. or 110-120 volts for A.C. models. Features of the air cooled units include light weight (starting at 95 lbs.) moisture proof automatic circuit breaker, moisture proof windings, air intake cleaner and fuel tank integral. The Bardco totally enclosed water cooled models are available in 3,000 and 5,000 watt sizes A.C. or D.C. For Form B, 530 write the Bardco Mfg. and Sales Co., Dayton, Ohio, or Los Angeles, Calif.

"Controls" is the caption of Bender-Warrick Corpn.'s new catalog of electrical control equipment for pump operation, reservoir and tank elevation, sewage pumping, etc. The Bender-Warrick electrode type floatless pump controls for tank levels, collecting sumps, etc., are featured. Then follow many pages of B.-W. control units and panels, starters, relay switches, contractors. At the end are 3 pages of typical application diagrams of signal systems, pump control, elevation control and start-stop sewage pump control, without the use of floats. For a copy of Catalog 241 write Bender-Warrick Corpn., Birmingham, Mich.

"Engine Driven Pumping Units" are subject of a new Allis-Chalmers leaflet covering their complete self-contained engine driven centrifugal pumping units for service entirely independent of any outside source of power supply. It illustrates various sizes and types of units applicable to irrigation, gravel washing, coal washing, fire protection and from municipal standby or emergency service—water or sewage. It includes easily read centrifugal pump selection table for picking suitable unit, and overall dimension sheet. For leaflet B-6153 write Allis-Chalmers Mfg. Co., Milwaukee, Wis.

"4 Vital Factors" is a Fairbanks-Morse bulletin which reviews the importance of engineering, manufacturing, testing and company integrity as the four vital factors entering into the production of F-M Pump "Tailored to Match" requirements precisely. The bulletin also emphasizes the advantages of having one firm responsible for the motor as well as the pump and relates how this factor is strengthened through 110 years of successful experience.

A Brass Pipe Handbook is something of a companion piece to the useful Copper Tubing Handbook, also produced by the Copper and Brass Research Association and reviewed in this column of our March issue. The Brass Pipe Handbook is possibly of most value to those designing or installing interior piping systems for buildings, but has much of interest to water works operators. Chapter I deals with the characteristics of brass pipe and proper composition for waters of vari-

(*Continued on next page*)

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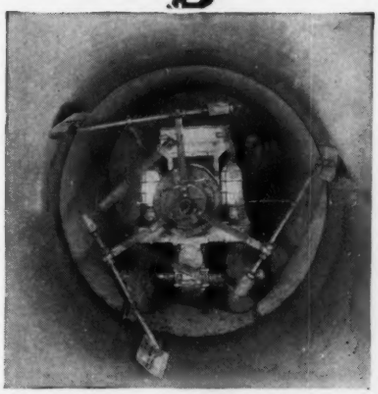

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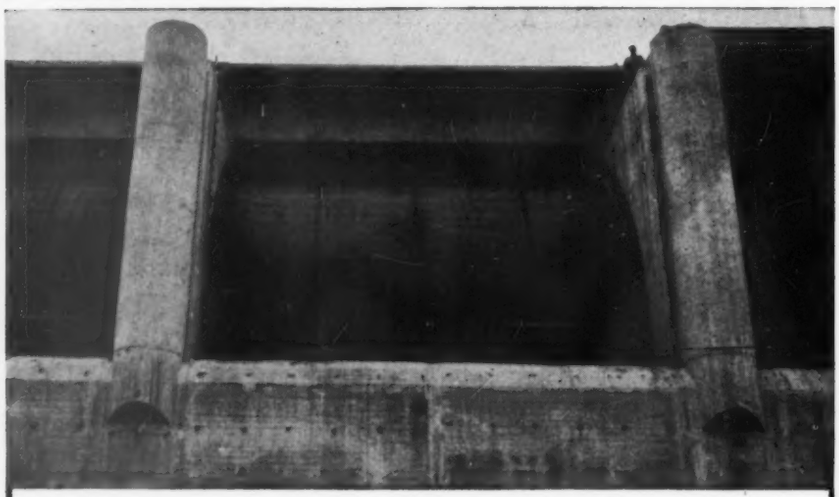
ous types. Chapter II captioned "Craftsmanship" is a primer of pipe tools and their use; methods most suitable for cutting, threading, bending, jointing and installing brass or copper pipes. Chapters III and IV deal with design of piping for various services, proper sizes of brass pipe to employ, layout of piping, methods of support and hanging, etc. We can recommend this Brass Pipe Handbook, as a highly useful publication which may be had for the asking. Write the Copper and Brass Research Ass'n., 420 Lexington Ave., New York City.

Cleansing Water Meter Parts is the subject of an illustrated article of interest to water works operators which appears in he April-May issue of the Oakite News Service, house magazine of Oakite Products, Inc. The article describes an improved method of removing hard water scale, rust and other deposits that enables one Southwestern water meter repair shop to recondition water meters without the laborious, time-consuming wire brushing and scraping formerly required. Copies of this interesting article are available upon request. Write to Oakite Products, Inc., 57 Thames Street, New York, N. Y.

"Fire Guns—by Hauck"—are described as "utility torches for 101 uses." They are portable outfits, much like a one-man insecticide sprayer (2 to 4 gals.) slung from the shoulder; the nozzle is the torch. The powerful smokeless flame is "windproof" and the outfit is employed as a general thawing device in winter and more prevalently as a weed destructor in summer. The fuel is kerosene oil or gasoline as preferred. Additional applications include thawing of piles of gravel, sand, etc., hydrants, valves and sluice gates, manhole covers; drying concrete walls before water proofing; removing dust and tubercules, old paint, etc.; sterilization of infested areas. For a copy of Hauck's Fire Gun Bul. No. 1034, write Hauck Mfg. Co., 124 Tenth St., Brooklyn, N. Y.

"Automatic Control for Water and Sewage Sludge Pumps" are presented in a comprehensive revised 1940 edition of the earlier published bulletins from Automatic Control Co. of St. Paul, Minn. The revised bulletins, now bound in a single filing catalog, are devoted to "Tanktrols" for pump control in connection with elevated tanks or reservoirs; "Floattrols," which are multi-circuit float switch controls for sequence operation of pumps; "Selectrols" for program operations of two or more pumps in sewerage systems; "Duotrols" for automatic operation and balance between air and water ratio in connection with pneumatic tanks; Float Switches and Accessories for the several systems. If your file has not the 1940 revision of Automatic Control units, it should be brought up to date by requesting 1940 Catalog C-3 from Automatic Control Co., 1005 University Ave., St. Paul, Minn.

"1,000,000 Hours of Performance"—is a brochure from Caterpillar Tractor Co. which features the history of 78 Diesel-powered Caterpillars that have operated a total of more than 1,000,000 hours to date. The brochure states that none of the machines described and pictured are hand-picked; and, that maintenance and performance records are those from actual owners. Copies of this book or other Caterpillar information may be obtained by writing Caterpillar Tractor Co., Peoria, Ill.



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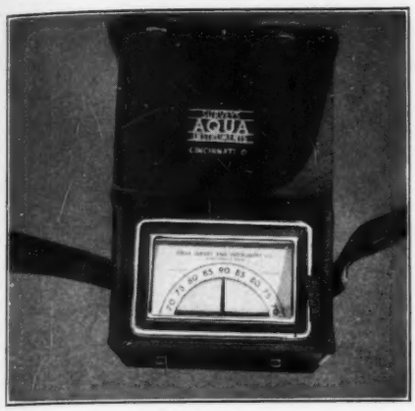


View When in Use

How Employed

● A new Valve Box Locator, with several improvements, has just been announced by the Aqua Survey and Instrument Co. of Cincinnati.

The trimness and ease with which the new AQUA Locator is used are clearly in evidence in the accompanying pictures. The instrument comes in a neatly fitted leather carrying case, and the shoulder strap proves to be a stoop saving accessory as well as carrying a convenience.

There is nothing claimed by the manufacturer for the long utilized dipping needle principle employed, but the behavior of the magnetic needle has been vastly improved and brought under control. The needle of 35% cobalt alloy steel takes a stronger magnetic charge and holds it much longer than ordinary steel needles do. It sets in finely adjusted sapphire bearings, the bracket being mounted on gum rubber to protect against jolts and jars. Possibly the greatest improvement in the minds of operators is the Aqua air-dampened needle, this dampening putting an end to needle fly-wheel action and the marked pendulum swing, so annoying and time consuming in using ordinaly valve box locators. Another is the exclusive Aqua reading mirror arrangement that permits the no-stoop top view reading of the instrument. The compass feature is also of interest, since it is simple to use the locator as a direction finder by merely turning the front of the case to face up position. That this very neat package is of practically vest pocket dimensions is another item of interest aside from its performance attributes and, certainly the price seems attractive enough.

For further information and illustrated folder, write Aqua Survey and Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.

PARMANCO

HORIZONTAL DRILLS

Left picture shows how PARMANCO drills under street without disturbing surface. Job at right obstructs traffic and creates a public hazard.

STOP . . . and THINK

That cutting pavements causes more damage than traffic.

That trenched yards are eyesores for years.

That public hazard can be eliminated.

That obstructing traffic is not necessary.

That you now can put services in to grade.

That you can save money, time and create good will by using PARMANCO. PARMANCO Utility Drills are made in two sizes, PARMANCO JUNIOR for drilling 4 inch holes up to 50 feet, and the PARMANCO GENERAL UTILITY for drilling longer distances or drilling larger holes.

PARMANCO General Utility Machines increase public good will and save money through eliminating PAVEMENT CUTTING • TRAFFIC OBSTRUCTIONS • TRENCHED YARDS • PUBLIC HAZARDS.

Write Us Regarding Your Drilling Problems

PARIS MANUFACTURING CO., INC.

PARIS, ILLINOIS

not 1 out of 2
not 3 out of 4
not 4 out of 5
but
more than 9 out of 10
FREE WORKING SAMPLE

90%+ is mighty close to being unanimous. And that's the percentage of engineers who have become permanent users of *PALCO Packing after testing a sample in a stuffing box.

Why does this packing sell itself so completely? The answer lies in its long, strong, high-quality fibres, and its large reserve supply of lubricant, secured by impregnating each individual strand with a special lubricant under pressure while hot.

Make This FREE Test

You, too, are invited to make the test that has convinced so many other engineers. Just send us your name and address on the coupon below, stating the size and service for the packing and a working sample will be sent you, without charge or obligation.

Greene, Tweed & Co.
Bronx Blvd. at 238th St.,
New York, N. Y.

Send the Coupon

*PALCO
PACKING
for water
*Reg. U. S. Pat Off

Made by the manufacturers of *PALMETTO

Greene, Tweed & Co., New York
Bronx Blvd. at 238th St., New York, N. Y.

Send free working sample of packing....size,
for ..... service
Name .....
Company .....
Address .....

The "Test-A-Tone," a Sensitive Water Leak Detector

● The "Test-a-Tone," the newest thing in instruments for detecting and tracing water leaks, has just been announced by Joseph G. Pollard Co. of New York.

The "Test-a-Tone" is something of a super stethoscope for trouble finding in general, by magnification of vibrations and machinery, clicks or knocks. It was, in fact, developed for use by mechanics and engineers listening for and locating foreign noises in compressors, engines, and machines of various

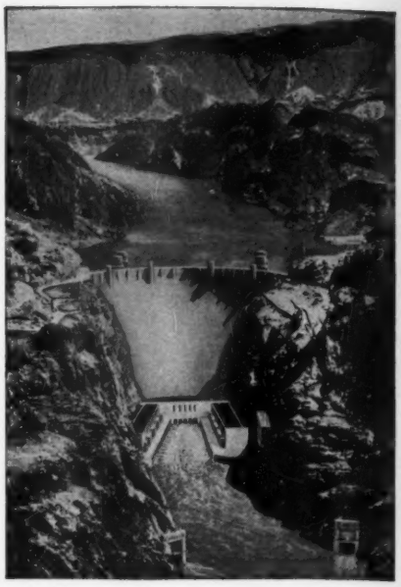
sorts. Its application as an extremely sensitive and selective instrument for detection of vibrations set up on pipe lines, fire hydrants, etc., by high velocity water leaks through joints, fittings, etc., has proven its worth to water works and sewerage operators for this purpose as for others.

A feature of particular interest, in addition to the sensitivity boosting element, is the adjustment screw for volume control and selectivity. The latter is important in damping out extraneous background noises. It, however, is extremely simple and compact, no electric batteries being involved, and comes in the neat carry case. The rods are adjustable in length and one, for softening the sound if too great, is rubber tipped.

For more detailed description, and pictures showing its use for checking bearings and valves as well as water leaks, write the Joseph G. Pollard Co., Inc., 142 Ashland Place, Brooklyn, New York.

NATIONAL METER INTRODUCES THE EMPIRE "STREEEMLINE"

● The National Meter Division of the Pittsburgh Equitable Meter Co., will exhibit the Empire "Streeemline" Meter for the first time at the Toronto Convention of AWWA. The trade name, "Streeemline," has been chosen to de-



Bailey Meters AT
BOULDER DAM

● In Boulder Dam Power Plant as in many other new hydro-electric stations including Madden Dam and Norris Dam, Bailey Fluid Meters are installed on hydraulic turbines.

At Boulder Canyon, the Bailey Meters measure water supply through 13 foot diameter penstocks under an average head of 530 feet. These meters indicate and record the water flow in terms of cubic feet per second and continuously integrate in millions of cubic feet. The registers are operated by pressure connections in the turbine scroll casings.

While your project probably does not entail the volume and head of water that is being measured at Boulder Canyon, it is nevertheless, important that your measurements of flow and liquid level be accurately made by reliable equipment.

Write for complete information on the application of Bailey Meters to your problem. MU-19

BAILEY METER • COMPANY •
1072 Ivanhoe Road, Cleveland, Ohio
BAILEY METER COMPANY LTD., MONTREAL

scribe the smooth flow lines and unexcelled accuracy and low head-loss curves. The manufacturer announces that the "Streeemline," a four-bolt, frost protected meter, is a thoroughly modernized version of National's well known Empire Meter. It is further stated that this product embodies the same basic principle of oscillating piston measurement that has been time proven in hundreds of thousands of Empire Meters.

Due to the scientific design and proportion of the measuring chamber, with

dual inlet and outlet ports, the accuracy claimed for this meter is said to be even superior to that of Empire Meters built in the past.

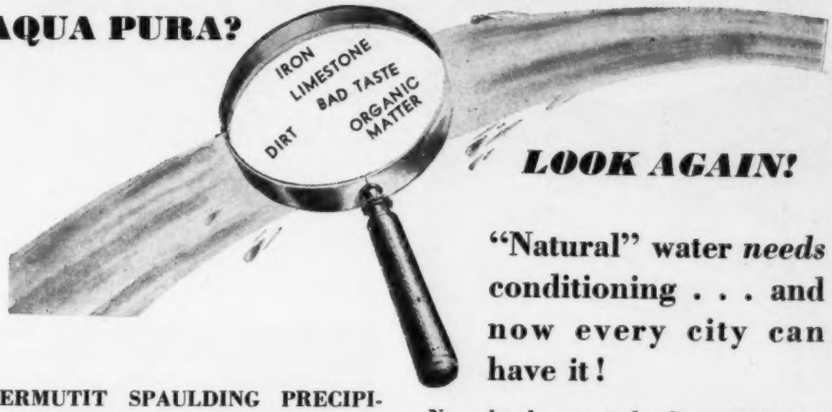
Extremely compact overall dimensions, made possible by a reduction in the number and size of interior castings, is one of many outstanding features. All working parts are fitted as a complete unit, without use of screws, before being inserted in the outer case.

Complete frost protection is claimed for this meter. The cast iron bottom plate, protected against corrosion with a coat of Resistin, is designed to break in event of freezing. Since both the measuring chamber and the enclosed intermediate gear train housing utilize snap joint construction, without screws, the parts will separate when the frost bottom plate breaks, thereby giving protection to the working parts against damage or distortion. It is claimed that this design provides the first fully frost protected gear train.

The Empire "Streeemline," for domestic services, is furnished with either straight or circular reading dial type register, with large red center test hand, recording in gallons, cubic feet, other units of measurement.

Literature completely describing and illustrating the Empire "Streeemline" Water Meter will be sent to those interested by writing to the National Meter Division, Pittsburgh Equitable Meter Company, 4207 First Avenue, Brooklyn.

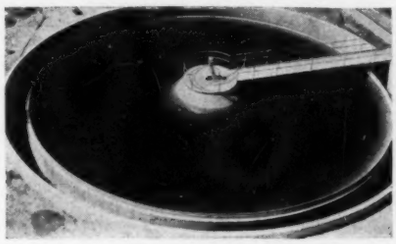
AQUA PURA?



LOOK AGAIN!

"Natural" water *needs* conditioning . . . and now every city can have it!

PERMUTIT SPAULDING PRECIPITATOR makes water soft and clear.



FEATURES

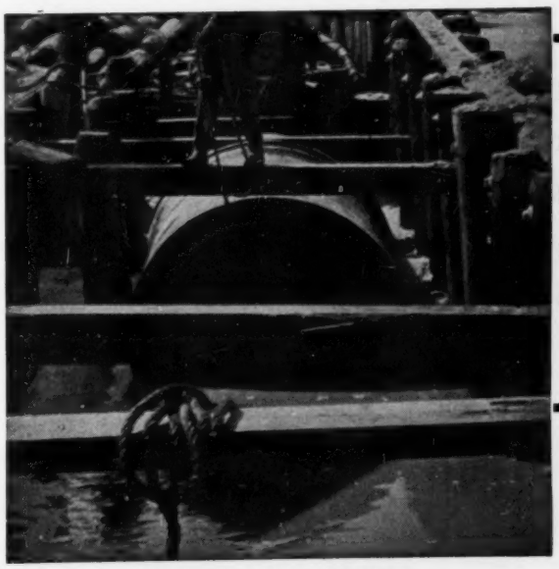
1—Sludge is kept suspended, speeding precipitation and acting as a contact filter; 2—Conical filter chamber lowers velocity of rising water, keeps sludge uniformly dense for filtering.

New developments by Permutit* now put the benefits of soft water within reach of every community. Modern equipment—like Permutit's Spaulding Precipitator—takes less space, makes bigger savings.

Let Permutit place its 25 years of water conditioning experience at the disposal of *your* engineers. Write to: The Permutit Company, Dept. G1, 330 West 42nd Street, New York, N. Y.

*Trademark Reg. U. S. Pat. Off.

PERMUTIT
WATER CONDITIONING HEADQUARTERS



84" pipe—Spring Lake, N. J.

FLANGED PIPE

FLEXIBLE JOINT PIPE

BELL & SPIGOT PIPE

SPECIAL CASTINGS

SHORT BODY BELL & SPIGOT SPECIALS

Large stock enables us to make prompt shipments.

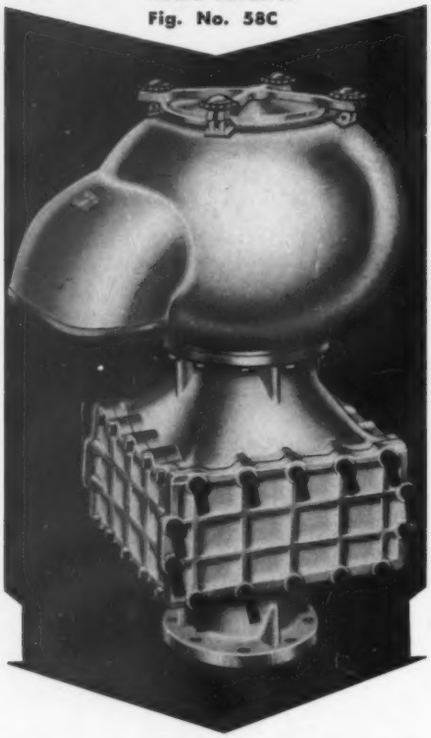
CAST IRON PIPE

SIZES 2" TO 84"

Warren Foundry & Pipe Corp.
11 Broadway, New York

Warren Pipe Company of Mass., Inc.
75 Federal St., Boston

"VAREC" Approved Pressure Relief & Vacuum Breaker Valve with Flame Arrester
Fig. No. 58C



"VAREC"
SEWAGE GAS
CONTROL and
Safety Devices

"Specify Varec" is the sanitary engineer's by-word for the control of toxic and combustible gases with safety, economy, and efficiency.

Thousands of "VAREC" installations in Sewage Treatment Plants, large and small, are continually protecting life and property from explosion and fire.

The "VAREC" Engineering Department and laboratory are at your command at any time to collaborate with you on your particular installation.

"VAREC" Sewage Gas Control and Safety Devices Catalog and Handbook, S-3, profusely illustrated with photographs of actual installations, charts, diagrams, and prices, is yours for the asking.

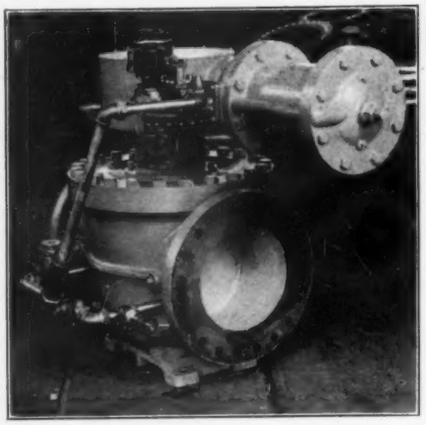
"VAREC" Approved Products

Pressure Relief and Flame Trap Assemblies • Pressure Relief and Vacuum Breaker Valves • Flame Arresters • Waste Gas Burners • Flame Checks • Back Pressure Regulators • Pressure (Reducing) Regulators • Check Valves • Sediment and Drip Traps • Manometers • Pressure (Explosion) Relief Valves • Manhole Covers • Handhole Covers • Sampling Hatches and other safety appurtenances.

THE PACE SETTER SINCE 1928
The VAPOR RECOVERY SYSTEMS COMPANY
COMPTON • CALIFORNIA
NEW YORK CITY — HOUSTON, TEXAS — CLEVELAND, OHIO — TULSA, OKLAHOMA
Agencies Everywhere

NEW "ROTOVALVE"

• S. Morgan Smith announces the new "Rotovalve" here pictured as an interesting example of advanced valve design and control mechanism. The electrical control being inter-connected with the pump motor circuit thus assures a synchronized action of both units, pump and valve, *as one*, resulting in smoothness and positiveness of operating results.

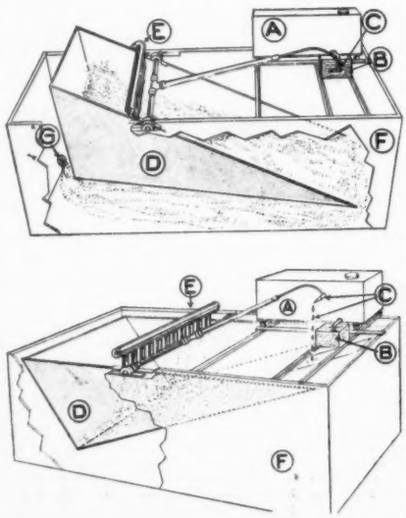


This valve is a 14" Hydraulically Operated Rotovalve, designed for 250 lb. working pressure, for pump discharge service.

It is one of the recent designs, in the complete line of Rotovalves for water and sewerage since built by the S. Morgan Smith Co., York, Pa.

New Automatic Liquid Proportioner

• Dr. Robert L. Furby of Portland, Oregon, has developed a very simple proportional solution feeder for treatment of water, sewage, swimming-pools,



etc. with hypochlorite, lime, coagulants or other chemicals.

(*Continued on next page*)

ROUGH ON RUST!

The Rusta-Restor Method of Tank Protection

There's no percentage in letting rust accumulate on your water tanks and filter beds. **Get rid of it electrically**—and **stay** rid of it, **by electricity**—the only known means of POSITIVE PREVENTION:

RUSTA-RESTOR TRADE MARK REGISTERED
Circular on request

RUSTA RESTOR CORPORATION
1480 W. State St. Fremont, Ohio

WATER TREATING EQUIPMENT

Gravity and Pressure Filters, Softeners, Recarbonators, Chemical Diffusers, Cooling Towers, Standard and Special Equipment for any Water Treating Problem

MUNICIPAL SERVICE CO.
Dwight Bldg., Kansas City, Mo.

The method of operation of this feeder is clearly enough pictured in the accompanying illustrations as to need little description. The solution from the stainless steel tank (C) flows into the dipping receptacle (B) to keep it filled. The water etc. being treated flows into tilt bucket or hopper (D), which dumps when the balance is upset by the filling. When the tilt hopper dumps the little spoon (C) dips into the solution. Upon discharge of its contents hopper (D) returns to its filling position and simultaneously the charge of chemical solution (scooped up by the little dipper) is emptied into the hopper where through mixing of solution and liquid being treated takes place during filling.

The Dr. Furby Proportioner is constructed of 12-gauge iron (welded) and protected with chlorine resistant coating. It is finished in Duco white. The unit here shown is enclosed in a metal housing, but is readily accessible through an end door. The solution chamber, receptable and dipper are of stainless steel. If desired a second solution chamber and dipper can be provided, so as to feed with one unit two different solutions when such is desirable — (ammonia and chlorine; chlorine and soda ash; chlorine and a coagulant; copper sulphate and chlorine, etc.)

Of primary interest is the fact that the feeder has but one moving part supported by a steel shaft in special bearings. The overall size of the 50 gallon unit (most popular size) is 3½ ft. wide by 6½ ft. long by 4 ft. 10 in. maximum height of enclosure. The shipping weight is approximately 788 lbs. uncrated.

Dr. Furby originally designed this feeder for chlorination at C.C.C. camps and now makes it available for general use. The dosage is varied by changing the strength of chemical solution or by altering the size of the dipper. An illustrated folder is available and further details can be had by writing Dr. Furby's Liquid Proportioner Co., 1015 Bedell Bldg., Portland, Oregon.

New Design in Printing Machines

• New simplicity of design and new operating usefulness are embodied in a new printer just announced by Charles Bruning Company, Inc., of New York. Known as the Model "55" BW Printer, this machine is said to be the most compact printer of its capacity on the market, since it measures only 32 inches wide, 62 inches long, with 48 inches high.

The Model "55," a 42-inch printer, operates with either cut sheets or roll stock. It prints ink tracings at from 12 to 15 feet per minute. A full-view speed indicator placed at the center of the

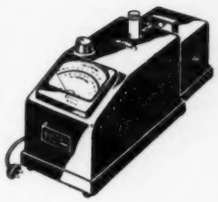
(*Continued on next page*)

Leading Apparatus

for the WATER WORKS *and* SEWERAGE LABORATORY

The HELLIGE TURBIDIMETER. Turbidity measurements (SiO_2) and sulphate determinations can be made with greater simplicity and speed *without* the preparation and use of standard suspensions. Reads all turbidities down to zero.

HELLIGE COMPARATORS are unsurpassed in durability, handiness, and convenience. Perpetually accurate glass standards are available for pH control and all popular A.P.H.A. and A.W.W.A. methods.



The HELLIGE - DILLER PHOTOELECTRIC COLORIMETER is a precise photoelectric instrument for accurate and *always* reproducible colorimetric determinations. No standards required. Ideal for the determination of minute quantities of phosphorus, silica, sulphates, chlorides, and dissolved oxygen.

HELLIGE GLASS ELECTRODE pH-METERS—COUNTING APPARATUS—COUNTING CELLS AND MICROMETERS.

Write today for informative 28-page bulletin No. 602.

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HEADQUARTERS FOR COLOR STANDARDS AND COLORIMETRIC APPARATUS

HYDRO-TITE

ONE POUND does the work of four pounds of lead. Much easier to use than lead and requires no caulking.

HYDRO-TITE joints are strong, very flexible and tight.

Write for our free trial offer.

HYDRAULIC DEVELOPMENT CORPORATION

MAIN SALES OFFICE - 50 CHURCH STREET, NEW YORK
GENERAL OFFICES AND WORKS - WEST MEDFORD STATION BOSTON, MASS.

OVER 25 YEARS WITHOUT A FAILURE

Weed Control with BENOCLOR 3 IS GOING APACE

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Now is the time to prevent excess aquatic plant life in feeder lakes with

BENOCLOR 3.

Weeds that never grow cannot deplete oxygen late in the summer.

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Send for New Folder

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CLOROBEN CORP.

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PREPARE FOR EMERGENCIES WITH

VALVES
HYDRANTS
AND WATERWORKS ACCESSORIES

M & H products, including pipe line accessories, are well known for high quality of material and expert workmanship. They are made according to standard specifications and have been used for many years throughout the country. Write for Catalog No. 34.

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

ODOR and TASTE are health factors-too

THE WATER SUPPLY that pleases nose and palate is an important contribution to community health—people drink more of it.

ESOTOO* is the answer to a simple, sure and more economical method of controlling residual chlorine—especially in "break-point" chlorination.

ESOTOO* is the Ideal De-Chlorinator.

Write for bulletin which describes the "Virginia Method" of applying Liquid Sulfur Dioxide for Dechlorination.

*ESOTOO is "Virginia's" Trade Name for Liquid Sulfur Dioxide.

VIRGINIA

VIRGINIA SMELTING COMPANY
WEST NORFOLK, VIRGINIA

front, above the feed board, makes the speed of the machine readily visible to the operator at all times.

An exclusive feature of the Model "55" Printer is its new print and tracing return. The entire top of the machine serves as a return tray, and the return is so designed that the tracing enters the tray on top of the print—in exactly the same way as it is inserted in the machine. No reversing of the tracing is necessary when reinserting it into the machine. Furthermore, as they emerge from the printer onto the tray, exposed sheets stack themselves almost automatically.

The light source of the new Model "55" Printer is a 55 watt new-type mercury vapor quartz lamp. This quartz lamp furnishes uniform exposure, without flickering, and is guaranteed for a life of 1000 hours. The lamp is installed in a revolving 9-inch Pyrex contact cylinder which provides almost perfect contact.

The Model "55" Printer is equipped with a double centrifugal blower to reduce operating noise. In addition, the transmission and motor are resiliently mounted to reduce vibration. An automatic clutch, operated by a simple, wide-range foot pedal, releases the feed roller so the tracing may be adjusted or removed when necessary.

A hinged section at each end of the printer allows ready access to all electrical controls and drive mechanism for cleaning or servicing. An automatic switch shuts off the light when the end housing of the tube and cylinder are removed.

The "55" Printer is made for two currents—220 volts A. C. 60 cycles, or 220 volts A. C. 50 cycles. Operating electrical requirements for the entire machine is only 3800 watts.

For further details write, Charles Bruning Co., Inc., 100 Reade St., New York City.

IMPROVED METALLIZING GUN

A new and improved type of hand-gun employed in the "metallizing" proc-

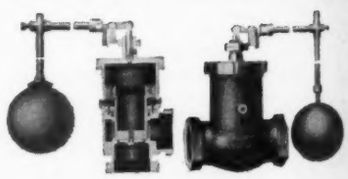
(*Continued on next page*)

This, concisely put, is what you get when you use *Tegul*-MINERALEAD in jointing your Bell and Spigot Pipe. • The ingot form is impervious to rain and flood. • This compound works with pipe of any diameter, isn't bothered by terrain conditions and has the stamina to withstand far greater vibration and punishment than it will ever meet in service. • The cost will surprise you pleasantly. • For complete information, write The ATLAS MINERAL Products Company of Pa., Mertztown, Pennsylvania.

Tegul- MINERALEAD
For Jointing Bell & Spigot Pipe

See pages 56 and 57 of our new 96-page catalog for information on these

STANDARD COLD WATER FLOAT VALVES



Furnished in sizes ½" to 2" bronze, screwed ends, these Float Valves are recommended for cold water service where minimum inlet pressure is not less than 10 pounds per square inch.

Valves may be arranged with remote pilot control valve in lieu of integral lid pilot valve as shown; also, to function on differential water levels—that is, to close at desired full-tank level, but not re-open against influent pressure until the tank level lowers to a predetermined depth.

GOLDEN-ANDERSON VALVE SPECIALTY CO.
Fulton Building Pittsburgh, Pa.

bone-dry

The **PERFECT PACKING**

• Is the newest thing in joint packing, the invention of a water works superintendent. A real Bone Dry perfect and uniform joint. No bacteria — adds flexibility to pipe line. Saves labor, reduces construction time and costs, eliminates bell holes, cushion shock, and retards electrolysis.

Write for complete information

WATER and SEWER EQUIPMENT CO.
ROME, N. Y.

THE NATIONAL METHOD
BEFORE CLEANING
AFTER CLEANING

CLOGGED PIPES

Made Good as New

THE NATIONAL METHOD OF WATER MAIN CLEANING makes your old pipe practically as good as new. Every department is subject to loss through the ravages of time upon its distribution system. The cleaning out of this foreign matter inevitably leads to increased pressure and flow, improved health conditions, and lowered operating costs.

Our illustrated Booklet, "The Cleaning of Water Mains," will be sent upon request.

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30 Church Street, New York, N. Y.

BRANCH ADDRESSES
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115 Peterboro St., Boston, Mass.
910 William Oliver Bldg., Atlanta, Ga.
7103 Dale Ave., St. Louis, Missouri
208 E. Forsyth St., Jacksonville, Fla.
3812 Castellar St., Omaha, Nebraska
501 Howard St., San Francisco, Calif.
2028 Union Ave., Montreal, Canada

ess is announced by Metallizing Engineering Co. of New York.

The process of metallizing consists of spraying (atomizing) molten metal onto worn surfaces of metal parts to be built up, or surfaces to be protected against corrosion. The metal to be applied comes in wire coil form and is automatically fed through the gun where it is melted by a concentrated blow-torch flame and immediately atomized from the nozzle by compressed air.

As a hand tool, the gun is used for coating large structures and items of equipment with zinc, lead or aluminum as a protective film against corrosion. As a lathe tool, it is employed for building up worn parts, shafts, valve stems, plungers, bearings, etc., with stainless steel, bronze, monel metal, etc. (In respect to the first use we understand that the down-stream faces of flood gates of the Cooper-Santee Dam have been protected with zinc "metallizing"; the up-stream faces with Bitumastic enamel—Ed.)

The improved (Type 2E) gun has two important new features—(1) the "controlled power unit," which gives an absolutely uniform and steady wire feed, and eliminates gear changes; (2) the "Universal Gas Head" allows use of any of the compressed gas fuels, natural or city gas, without the necessity of changing heads.

For further information, write Metallizing Engineering Co., 2109—41st Ave., Long Island City, New York.

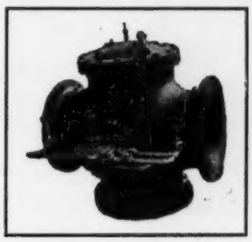
Keeping Packing Glands Soft (A Shop Hint)

To keep packing glands soft apply cylinder oil in which collidal graphite is suspended. The graphite particles penetrate the packings, keeping them soft, allowing more perfect joints and reducing rod or stem scoring. Advantage of the colloidal graphite is that its extremely fine particle size permits complete penetration.

This suggestion is offered by the manufacturer of colloidal graphite—the Atcheson Colloidal Corp., of Port Huron, Mich.

ROSS
AUTOMATIC VALVES

Reducing — Combination
Relief — Surge
Altitude — Float
Back Pressure — Differential



ALTITUDE VALVE
for
Control of elevation and heads into and out of tanks, basins and reservoirs.

ROSS VALVE MFG. CO., Inc.
P. O. Box 595 Troy, N. Y.

Wherever **SEWAGE GAS** *IS UTILIZED!*

Connelly IRON SPONGE

Protect your valuable equipment against costly Sulphur damage by the Connelly method of gas purification. Let Connelly engineers give you the benefit of their 65 years of experience in this specialized field. Consult them today. No cost or obligation.

Connelly H2S Testers

Quick, accurate tests made in a few moments using dry, pretreated discs. No messy lead acetate solution to bother with. "Handiest device of its kind", say those who have used it. The time saving alone quickly pays for it.

WRITE FOR ILLUSTRATED BULLETINS

CONNELLY
IRON SPONGE & GOVERNOR COMPANY
CHICAGO, ILL. • ELIZABETH, N. J.

REAL SURFACE PROTECTION
with **SHERWOOD'S** specifications is
ECONOMICAL, EFFECTIVE and **DURABLE**

R S P ASPHALT EMULSION FOR ROOF COATINGS
R S P SEMI-MASTIC FOR NON-SLIP FLOORS
R S P PLASTIC FOR EXPANSION JOINTS AND CAULKING

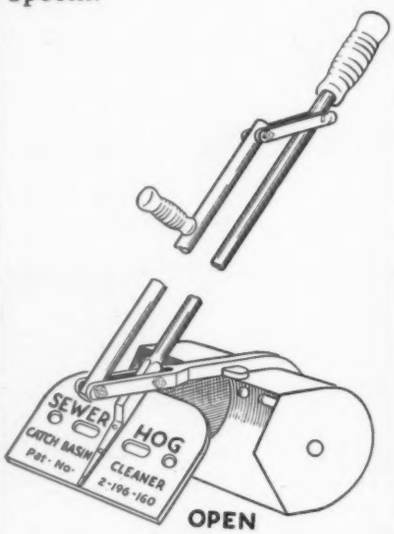
THEY ARE NOT COAL TAR PRODUCTS

Special instructions are gladly supplied for the many uses for these exceptional products. We invite your questions on waterproofing problems of any nature and assure you of our cooperation.

SHERWOOD WATERPROOFING CORPORATION
53 PARK PLACE NEW YORK, N. Y.

"Sewer Hog"

Turbine's New Patented Catch Basin Cleaner eliminates old fashion Catch Basin Spoons.



Simple, inexpensive; pays for itself every time used.

TURBINE SEWER MACH. CO.
5210 W. State St., Milwaukee
276 Lafayette St. New York, N. Y.

GASKET AND FORM
The Perfected Method for Making SEWER PIPE JOINTS OF CEMENT

- No jute used—gasket centers spigot.
- Definite space in each joint for cement.
- Form confines cement-grout to lower portion of joint.
- Particularly advantageous in water-bearing trenches.
- Infiltration minimized.

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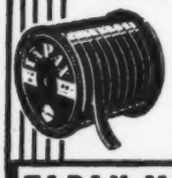

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WITH THE MANUFACTURERS

Crane Co. Elects Rumely Vice President in Charge of Manufacturing

● Crane Co., Chicago, announces the election of Mr. V. P. Rumely as Vice President in Charge of Manufacturing, to succeed Mr. J. H. Collier who was made President earlier this month. Mr. Rumely has been Works Manager of the Crane Chicago plant for the past four years, during which he has been very closely associated with Mr. Collier.

Born 52 years ago in La Porte County, Indiana, Mr. Rumely studied mechanical engineering at Purdue University, and later at the University of Wisconsin, graduating in 1912. His first job after leaving college was in the farm implement plant of his grandfather, M. Rumely, in La Porte, Indiana. (Later known as the Advance Rumely Co.) In 1914-15 he was with the Buick Motor Co., and in 1916 went to the Hudson Motor Co. Starting in the Hudson shops, he progressed through every stage of production management to Superintendent and Factory Manager, the position he held when he resigned to join the Crane organization in 1937.

Northrup Appointed Agent for Taylor Equipment

● W. A. Taylor and Co., of Baltimore, producers of the well known line of Taylor Slide Comparators, color standards, indicators and standard solutions for pH, residual chlorine, color, iron etc., and other laboratory equipment, have recently appointed Northrop & Co., Inc., 50 Church St., New York as agents for the full line of Taylor equipment.

Morris Appoints New Representative in Detroit District

● Morris Machine Works, Baldwinsville, New York, manufacturers of centrifugal pumps, hydraulic dredges and steam engines, announces the appointment of Mr. H. J. Lynch as their new representative in the Detroit District. Mr. Lynch is located at 403 Kales Building, Detroit, telephone Randolf 6021.

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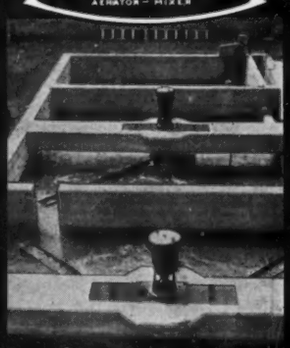

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Link-Belt Promotes Ewell and Woerwag

L. M. Ewell C. A. Woerwag

● Mr. George L. Morehead, vice president in charge of eastern operations, Link-Belt Company, announces that Mr. Laurence M. Ewell has been appointed general manager of eastern division operations, with headquarters in Philadelphia.

Mr. Ewell, who has until now been export manager, and manager of the company's New York office, will be succeeded in that position by his very able assistant, Mr. Carl A. Woerwag, with headquarters in New York as heretofore.

Mr. Ewell, a graduate of the Link-Belt engineering department, entered the employ of the company in 1906 after graduation from the U. S. Naval Academy.

Mr. Woerwag entered the employ of the company in 1910, after graduating from Lehigh University.

BUILDERS TO OPERATE UNDER NEW NAME

● Directors of Builders Iron Foundry, Providence, R. I., announce that on and after May 1, 1941, this Company will conduct its metering business under the name of Builders-Providence, Inc.

It is pointed out by D. K. Bartlett, Vice President, that this is a change of name only. In fact, Builders-Providence, Inc. is a division of Builders Iron Foundry and has the same directors and officers.

Established in 1820, Builders is one of the country's oldest industrial concerns—a company that has been doing business "at the same old stand" for 121 years.

Scon after the invention of the Venturi Tube by Clemens Herschel, in 1887, Builders acquired exclusive manufacturing rights and laid the foundation for "The Venturi Meter."

A-C Names Hill Chief of Industrial Relations

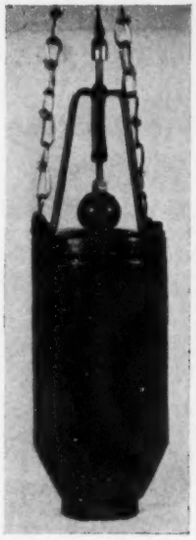
● In far reaching plan to promote cordial relationship between employees and management of the Allis-Chalmers Mfg. Co., Max W. Babb, president, announced today that Lee H. Hill, who was elected vice-president at the annual meeting of directors May 9, will head up a newly created Industrial Relations Department.

(Continued on next page)

P-G TANK SAMPLER

Easy to operate — Always Works Foolproof

Sewage engineers find the new P-G Sampler pays for itself in one month—in pumping and fuel costs



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In his new capacity, Mr. Hill, formerly assistant manager of the electrical department, will be in charge of collective bargaining, grievance procedure, employment, wage policies and levels and all other subjects which bear on management-employee relations.

"For some years past Mr. Hill has made an intensive study of industrial relations, Mr. Babb declared," and has applied to this subject the same keen analysis of which he has proved exceptionally capable in other fields.

ROSS BURNS JOINS PITTSBURGH EQUITABLE

● Colonel W. F. Rockwell, President of Pittsburgh Equitable Meter Co., recently announced that Ross J. Burns had joined the company in the capacity of National Representative. Mr. Burns is well known in the water works field. For many years he was with the Badger Meter Manufacturing Company and previous to that connection had been in the plumbing and heating supply business. During World War I, he served in the United States Naval Aviation Corps.

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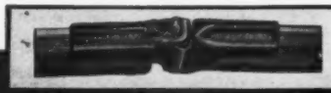

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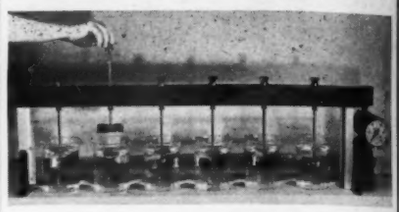

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FOREWORD

As publishers with many years of background we take especial pride in presenting this volume—the Reference and Data Number of WATER WORKS AND SEWERAGE for 1941.

This section, prepared by Linn H. Enslow, Editor, and John C. Black, Managing Editor, gives the equivalent of a handbook of data for designing engineers, managers and operators of water works and sewerage systems.

The contents represent matter carefully selected from the files of WATER WORKS AND SEWERAGE and other sources named in the text. In addition, a considerable effort has been made to secure the latest hydraulic tables and standards, and to present the most economical and modern methods.

Even though supplied at no charge to subscribers, beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Data Section as would be expected in a book devoted exclusively to the same type of material, and published separately.

NOTE

All who become subscribers during the current year may have a copy of this special issue so long as the extra supply printed for the purpose lasts—and, at *no extra charge* above the regular subscription rate.

Old subscribers will note that a certain amount of material in this issue has appeared in earlier issues. With the constant influx of new subscribers in mind, useful tables and graphs and other basic data will be repeated each year, other material will be retained for use in alternate years, while some will be permanently replaced with new or revised material.

It will henceforth be our endeavor not to repeat more than one-half of the material from year to year. It will, therefore, be necessary for each subscriber to possess issues of two consecutive years if he is to have available what may be termed a "complete" file of WATER WORKS AND SEWERAGE Reference and Data Material.

L. H. Enslow
Editor.

A BLUE-CHIP RECORD ISSUE

Since the beginning of these special annual issues each succeeding volume has been larger and more useful than that of the year previous. Now, this 1941 issue takes us into "The 400" class—for its heft of 404 pages represents a 60 page increase over 1940.

IN THE 1940 ISSUE

Below is an index to reference and data material which may be found in our last year's (1940) issue.
The items here listed are NOT to be found in this year's issue.

This listing together with the 1941 Index, gives what amounts to a "Consolidated Index" for two consecutive annual issues.
The practice is to be continued henceforth as an additional aid to those who find the reference and data sections useful.

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CLASSIFIED INDEX of PRODUCTS

Although this index is not published as a COMPLETE index of all materials and equipment used in the Water Works and Sewerage fields—it really is a very comprehensive list of products. It includes equipment and materials produced or marketed in this field by 195 manufacturers who have used WATER WORKS AND SEWERAGE in advertising such products during 1940 and 1941. Of these 195 manufacturers you will find the advertisements of 152 in this issue.

ABRASIVES
Carborundum Co., Niagara Falls, N. Y.

ACID, SULPHURIC AND HYDROCHLORIC
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
General Chemical Co., 40 Rector St., New York City.
Ozark Chemical Co., Tulsa, Okla.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ACTIVATED CARBON
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., 551 Fifth Ave., New York City.
Cliffs Dow Chemical Co., Marquette, Mich.
Darco Corporation, 60 E. 42nd St., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.

ACTIVATED SLUDGE EQUIPMENT
Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

AERATION APPARATUS
Aluminum Co. of Amer., Gulf Bldg., Pittsburgh, Pa.
E. W. Bachrach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas Cty, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

AGITATORS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

AIR BLOWERS
(See Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Glamorgan Pipe & Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ALTERNATORS, ELECTRIC
Bender-Warrick Corp., Birmingham, Mich.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Innis, Speiden & Co., 117 Liberty St., New York City.

ALUM, AMMONIA
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, BLACK
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ALUM (FILTER), COMMERCIAL, IRON-FREE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA, ANHYDROUS & AQUA
The Barrett Co., 40 Rector St., New York City, N. Y.
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I. (Aqua)
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Phipps & Bird, Inc., Richmond, Va.

ANEMOMETERS
M. C. Stewart, Ashburnham, Mass.

ANTHRAFILT
Anthracite Equipment Corp., 19 Rector St., New York City.

AQUA AMMONIATORS
(See Ammoniators)

AQUAPHONES
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.

ASBESTOS-CEMENT PIPE
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

AUTOMATIC FILTER AND SOFTENER CONTROLS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BASE-EXCHANGE SILICATE
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.

Permutit Co., 330 W. 42nd St., New York City.

BASIN CLEANERS
Champion Corp., Hammond, Ind.

BEARINGS, ROLLER & BALL
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 519 N. Holmes Ave., Indianapolis, Ind.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

BITUMINOUS COATINGS AND LININGS
Asphalt Products Co., Inc., Syracuse, N. Y.
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

BLEACHING POWDER
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

BLOWERS, AIR
De Laval Steam Turbine Co., Trenton, N. J.

BLOWERS (GASOLINE) ENGINE DRIVEN (PORTABLE)
Homelite Corporation, Port Chester, N. Y.

BOILER BLOWOFF APPARATUS
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.

BOILER FEED PUMP CONTROL
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

BOILER FEEDWATER TREATMENT
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Buromin Co., 300 Ross St., Pittsburgh, Pa.
Chain Belt Co., Milwaukee, Wis.
Cloroben Corp., 225 Mercer St., Jersey City, N. J.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hall Laboratories, Inc., 300 Ross St., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York City.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.
Quigley Co., Inc., 56 W. 45th St., New York City.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

BOILERS, GAS
American Radiator & Standard Sanitary Corp., Bessemer Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

BOILER WATER PURIFICATION APPARATUS
Chain Belt Co., Milwaukee, Wis.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Graver Tank & Mfg. Corp., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 301 W. Pershing Rd., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

BOOKS, TECHNICAL
John Wiley & Sons, Inc., 440 Fourth Ave., New York City.

BOXES, VALVES AND METERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.

BRASS GOODS
(See also Pipe, Brass.)
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Mueller Co., Decatur, Ill.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

BUFFER SOLUTIONS & MIXTURES
Heilige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

CALCIUM HYPOCHLORITE
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.

CALGON (See Corrosion Suppression and Water Stabilization)

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Schramm, Inc., West Chester, Pa.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS (Recarbonation).
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CAR SPOTTERS & HAULAGE SYSTEMS
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eimco Corp., 634 South Fourth West St., Salt Lake City, Utah.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill. (Bronze).
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

CAST IRON PIPE
(See Pipe.)

CATCH BASIN INLET
Northrop & Co., Inc., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

CATCH BASINS, CORRUGATED IRON
Armco Drainage Products Assn., Middletown, Ohio.

CATHODIC PROTECTIVE PROCESS
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.

CAUSTIC SODA
Diamond Alkali Co., Pittsburgh, Pa
Dow Chemical Co., Midland, Mich
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Michigan Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT PIPE
(See Pipe, Cement; Pipe, Concrete.)

CEMENT LINED PIPE
(See Pipe.)

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., Homer City, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Syntron Co., Homer City, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeder, Inc., 110 Washington St., Buffalo, N. Y.

CHEMICALS FOR WATER PURIFICATION
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.
Cloroben Corp., 225 Mercer St., Jersey City, N. J.
Darco Corp., 60 E. 42nd St., New York City.
Diamond Alkali Co., Pittsburgh, Pa
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Michigan Alkali Co., 60 E. 42nd St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Solvay Sales Corp., 40 Rector St., New York.

Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.
Tamms Silica Co., 228 N. LaSalle St., Chicago, Ill.
Virginia Smelting Co., 131 State St., Boston, Mass.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHEMISTS AND ENGINEERS
(See Directory of Experts, pages 108-109)

CHLORIDE, FERRIC
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORIDE OF LIME (CHLORINATED LIME)
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.

CHLORINATORS
(See also Hypochlorinators.)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHLORINE, LIQUID
Diamond Alkali Co., Pittsburgh, Pa.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Michigan Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan, Inc., Newark, N. J.

CHLORINE CONTROL EQUIPMENT
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York City.

CLARIFIERS, SEWERAGE AND WATER
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

CLEANING SEWER MAINS
Champion Corp., Hammond, Ind.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

CLEANING WATER MAINS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
National Water Main Cleaning Co., 50 Church St., New York City.

COAGULANTS & COAGULATION CONTROL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Innis-Speiden & Co., 117 Liberty St., New York City.
Michigan Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Asphalt Products Co., Inc., Syracuse, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

COATINGS AND LININGS
(See Bituminous Coatings and Linings.)

COCKS, CURB, METER, CORPORATION, ETC.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COLLECTORS (SLUDGE)
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS (COLOR)
Hellige, Inc., 3718 Northern Bldg., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPOUNDS, COUPLING
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR
De Laval Steam Turbine Co., Trenton, N. J.
Gardner-Denver Co., Quincy, Ill.
Roots-Connersville Blower Corp., Connersville, Ind.
Schramm, Inc., West Chester, Pa.

CONCRETE
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

CONCRETE—ARCHITECTURAL DESIGN
Roberts & Schaefer Co., 307 N. Michigan Ave., Chicago, Ill.

CONCRETE BREAKERS
Schramm, Inc., West Chester, Pa.

CONCRETE HARDENER
Connelly Iron Sponge and Governor Co., 3154 So. California Ave. Chicago, Ill.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS
Chain Belt Co., Milwaukee, Wis.

CONCRETE PIPE
(See Pipe, Concrete.)

CONCRETE Z-D ROOFS
Roberts & Schaefer Co., 307 N. Michigan Ave., Chicago, Ill.

CONDENSERS (STEAM)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTROLLERS, AUTOMATIC, ELECTRIC
Bender Warrick Corp., 128 Pierce St., Birmingham, Mich.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

CONVEYORS AND CONVEYING EQUIPMENT
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Elmco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Merrick Scale Mfg. Co., 180 Autumn St., Passaic, N. J.
Syntron Co., Homer City, Pa.

COOLING TOWERS
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Mueller Brass Co., Port Huron, Mich.

COPPERAS
Innis-Speiden & Co., 117 Liberty St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE, FLEXIBLE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

CORROSION SUPPRESSION
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.

COUPLINGS & CONNECTIONS, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COUPLINGS, FLEXIBLE
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Mfg. Co., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 220 S. Belmont Ave., Indianapolis, Ind.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COVERS, HANDHOLE, MANHOLE, SAMPLING
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

CRANES & HOISTS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

CULVERT CLEANERS
Champion Corp., Hammond, Ind.

CULVERTS
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Glamorgan Pipe & Foundry Co., Lynchburg, Va.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

DECHLORINATING EQUIPMENT AND CHEMICALS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.

Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Virginia Smelting Co., 131 State St., Boston, Mass.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DEMOLITION TOOLS
Schramm, Inc., West Chester, Pa.

DIAPHRAGM, PUMP
Ralph B. Carter Co., 53 Park Pl. New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DIFFUSERS—PLATES & TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DIGESTERS EQUIPMENT (SLUDGE)
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS (FILTER)
Ralph B. Carter Co., 53 Park Pl. New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

DRAINS, STORM
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

ELECTRICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINEERS AND CHEMISTS
(See Directory of Experts, pages 108-109.

ENGINES, DIESEL
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Schramm, Inc., West Chester, Pa.
Lawrence Stahl & Co., Inc., 21 West St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, SEWAGE SLUDGE GAS
Lawrence Stahl & Co., Inc., 21 West St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

FEED WATER HEATERS
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

FEED WATER TREATMENT
(See Boiler Feed Water Treatment)

FERRIC CHLORIDE, LIQUID & ANHYDROUS
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich. (Liquid & 60% crystal)
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Innis, Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid)
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC CHLORIDE FEEDERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

FERRIC SULFATE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Tennessee Corp., 621 Grant Bldg Atlanta, Ga., & Lockland, O.

FERROUS SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.

FILTER-AIDS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTER CLEANING PROCESS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Roberts Filter Mfg. Co., Darby, Pa.
Virginia Smelting Co., 131 State St., Boston, Mass.

FILTER CLOTHS
(Cotton, Wool & Jute)
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTER FABRICS, ACID-PROOF
Wm. W. Stanley Co., Inc., 40. Broadway, New York City.

FILTERING EQUIPMENT
Activated Alum Corp., Curtis Bay, Baltimore, Md.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
R. D. Cole Mfg. Co., Newman, Ga.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Filtration Equipment Co., 10 E. 40th St., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Underpinning & Foundation Co., Inc., 155 E. 44th St., New York City (For Sewage)

FILTER PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER & WATER SOFTENING PLANTS (COMPLETE)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
R. D. Cole Mfg. Co., Newman, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Neville Island P. O., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence. R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York City.

FILTERS—MAGNETITE
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.

FILTERS, VACUUM
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Filtration Equipment Corp., 10 E. 40th St., New York City.

FILTER UNDERDRAINS (PIPE & PLATES)
Armco Drainage Products Assn., Middletown, Ohio.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FILTER SAND
Activated Alum Corp., Curtis Bay, Baltimore, Md.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Laughlin Equipment Corp., 270 Madison Ave., New York City.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York City.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

FITTINGS, TEES, ELLS, ETC.
American Brass Co., Waterbury, Conn.
American Cast Iron Pipe Co., Birmingham, Ala.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
Ralph B. Carter Co., 53 Park Pl., New York City.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chain Belt Co., Milwaukee, Wis.
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOATLESS CONTROLS
(All Electric)
Bender Warrick Corp., 128 Pierce St., Birmingham, Mich.

FLOCCULATING EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

FLOOR GRATING
Arrowhead Iron Wks., 421 W. 5th St., Kansas City, Mo.

FLOOR STANDS
Crane Co., 836 S. Michigan Ave., Chicago. Ill.
Iowa Valve Co., Hubbell Bldg.,

Des Moines, Iowa (Manually and Electrically Operated)
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW METERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. and Allegheny Ave., Philadelphia, Pa.
Northrop & Co., Inc., 50 Church St., New York City.

FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., Philadelphia, Pa.

FLOW REGULATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL
Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., So. Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

GARBAGE DISPOSAL APPARATUS
Carborundum Co., Perth Amboy, N. J.
Chain Belt Co., Milwaukee, Wis.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

GAS DIFFUSERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS PUMPS
(See Pumps, Gas)

GAS PURIFICATION
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.

GAS REGULATORS
(Pressure & Flow)
(See Regulators—Water & Gas)

GATES, SHEAR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co. Chattanooga, Tenn.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

GATES, SLUICE
Armco Drainage Products Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.

GATES, TIDE
Brown & Brown, Inc., 456 S. Main St., Lima, Ohio.

GATE VALVE HOUSING
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES
(See Valves, Gate.)

GAUGES (Liquid Level, Pressure Recording)
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City (Pressure)
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

GEARS, SPEED REDUCING
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATORS, SETS, ELECTRIC & DIESEL ENGINES
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Northrop & Co., Inc., 50 Church St., New York City (Gasoline Driven Portable)
Lawrence Stahl & Co., Inc., 21 West St., New York City. (Also Standby and Gasoline)
Worthington Pump & Machy. Corp., Harrison, N. J.

GOOSENECKS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

GRATINGS, FLOORINGS
Arrowhead Iron Wks., Kansas City, Mo.

GREEN SAND (Zeolite)
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York City.

GRINDERS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.

GRIT CHAMBER EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HAMMERS, REPLACEABLE FACE
Greene, Tweed & Co., Bronx Blvd. at 238th St., New York City.

HOSE COUPLING WRENCH
Benton Tool Corp., 426 Engineers Bldg., Cleveland, Ohio.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Schramm, Inc., West Chester, Pa.

HYDRANT OPERATING VALVE WRENCH
Benton Tool Corp., 426 Engineers Bldg., Cleveland, Ohio.

HYDRANT PUMPS
(See Pumps, Hydrant.)

HYDRANTS (FIRE)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDROGEN ION EQUIPMENT
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

HYPO-CHLORINATORS
E. W. Bachrach & Co., Rialto Bldg., Kansas City, Mo.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

INDICATOR POSTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

INSULATION
Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.

IRON SULPHATE
Innis, Speiden & Co., 117 Liberty St., New York City.

JOINTING COMPOUND
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Lock Joint Pipe Co., Ampere, N. J.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, FILLER
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, FLEXIBLE PIPE
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Lock Joint Pipe Co., Ampere, N. J.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS, MECHANICAL (FLEXIBLE)
American Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
Weston's Gaskets & Forms, Adams, Mass.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, RUBBER RING
Water & Sewer Equip. Co., Rome, N. Y.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

LABORATORY APPARATUS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Carborundum Co., Niagara Falls, N. Y.
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Corning Glass Works, Corning, N. Y.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

MANHOLE CUSHIONS
(anti-Rattle)
Tapax Mfg. Co., Mamaroneck, N. Y.
Turbine Sewer Machine Co., Inc., 5210 W. State St., Milwaukee, Wis.

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Corning Glass Works, Corning, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

METER ACCESSORIES, BOXES, HOUSING, ETC.
Badger Meter Co., Milwaukee, Wis.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Worthington-Gamon Meter Co., Harrison, N. J.

METER COUPLINGS & YOKES
Badger Meter Mfg. Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Worthington-Gamon Meter Co., Harrison, N. J.

METERS, GAS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, PITOT
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co., Milwaukee Wis.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Worthington-Gamon Meter Co., Harrison, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Phoenix Meter Corp., Prince Bay, Staten Island, New York.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Worthington-Gamon Meter Co., Harrison, N. J.

METER WASHERS
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MIXERS, CHEMICAL
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

MIXERS, CONCRETE
(See Concrete Mixers)

MIXING EQUIPMENT
(Water & Sewage)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Ralph B. Carter Co., 53 Park Place, New York City.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Elmco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.

MOTOR STARTERS
Bender Warrick Corp., Birmingham, Mich.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

MOTORS, ELECTRIC
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

NIPPLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR CONTROL
Cloroben Corp., 90 Forrest St., Jersey City, N. J.
Permutit Co., 330 W. 42nd St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.

ODOR & CARBON EVALUATION AIDS
Darco Corp., 60 E. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
L. A. Salomon & Bro., 216 Pearl St., New York City.

OPERATING TABLES
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hyde-ro Rings (Ralph H. Hyde), P. O. Box 1, Campbell, Calif.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PACKING RINGS
Water & Sewer Equip. Co., Rome, N. Y.

PACKING, SELF LUBRICATING
Greene, Tweed & Co., Bronx Blvd. at 238th St., New York City.

PAINT, ACID RESISTING
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Asphalt Products Co., Inc., Syracuse, N. Y.
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

PAINTS, TECHNICAL
Quigley Co., Inc., 56 W. 45th St., New York City.
Sherwood Waterproofing Corp., 53 Park Pl., New York City.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

pH CONTROL FEEDERS
Proportioneers, Inc., 9 Codding St., Providence, R. I.

pH METERS & pH TESTERS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

PIPE, ACID PROOF
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Corning Glass Works, Corning, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Glamorgan Pipe & Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE AND TANK COATINGS
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE, BRASS AND COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 4th Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Glamorgan Pipe & Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CAST IRON SERVICE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Glamorgan Pipe & Foundry Co., Lynchburg, Va.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

PIPE, CEMENT LINED
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LININGS
Centriline Corp., 140 Cedar St., New York City.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

PIPE, COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

PIPE, CORRUGATED
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE CUTTING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE, DRILLS, JACKS AND PUSHERS
Paris Mfg. Co., Paris, Ill.

PIPE ENAMELS, PROTECTIVE—COAL TAR
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., Westfield, N. J.

PIPE, FELT WRAPPING
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Glamorgan Pipe & Foundry Co., Lynchburg, Va.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE—GALVANIZED, LIGHT-WEIGHT
(Quick Coupling, Transportable for Conveying Water)
Champion Corp., Hammond, Ind.

PIPE, GLASS
Corning Glass Works, Corning, N.Y.

PIPE JOINT COMPOUNDS
Atlas Mineral Products Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Quigley Co., Inc., 56 W. 45th St., New York City.

PIPE JOINTS, MECHANICAL
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
L. A. Weston, Adams, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE JOINT TOOLS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Servicised Products Corp., 6051 W 65th St., Chicago, Ill.

PIPE, LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE LOCATORS
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Northrop & Co., Inc., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Water Leak Detector Co., 166 N Third St., Columbus, Ohio.

PIPE PUSHERS
Atlantic Steel Co., 1775 Broadway, New York City.
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Glamorgan Pipe & Foundry Co., Lynchburg, Va.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete)
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE TAPPING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

PIPE TEST PLUGS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, WELDED STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co. Pittsburgh, Pa.

PIPE, WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PITOT TUBES
Pitometer Company, 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT, BLOWERS FOR
Roots-Connersville Blower Corp., Connersville, Ind.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.

POTENTIOMETERS
Heilige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

PRESSURE REGULATORS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

PROPORTIONING EQUIPMENT (CHEMICAL)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Syntron Co., Homer City, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

PUMP MOTOR STARTERS
Bender Warrick Corp., Birmingham, Michigan.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

PUMP PRIMERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.

PUMPS, ACID-HANDLING
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St. Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, BOILER FEED
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CENTRIFUGAL
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York City.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, CONDENSATION
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DEEP WELL
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Elmco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 325 W. 25th St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

PUMPS, DRAINAGE
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

PUMPS, JETTING
Northrop & Co., Inc., 50 Church St., New York City.

PUMPS, PORTABLE
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 So. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., 50 Church St., New York City.
Roots-Connersville Blower Corp., Connersville, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS SEWAGE
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Elmco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SLUDGE
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Elmco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.

Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SUCTION AND FORCE
Ralph B. Carter Co., 53 Park Place, New York City.
Edson Corp., 40 D St., South Boston, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York City.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SUMP
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, TURBINE
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, VACUUM
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Gardner-Denver Co., Quincy, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.

RAIN GAGES
M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RATE OF FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Neptune Meter Co., 50 W. 50th St New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

REAMERS
Mueller Co., Decatur, Ill.

RECARBONATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Ozark Chemical Co., Tulsa, Okla.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

RECORDING INSTRUMENTS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

RECUPERATOR
Carborundum Co., Perth Amboy, N. J.

REFRACTORIES
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.

REGULATORS, SEWAGE
Brown & Brown, Inc., 456 S. Main St., Lima, Ohio.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS (Pressure), WATER AND GAS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESERVOIRS
(See Standpipes and Tanks)

ROBOT FILTER AND SOFTENER OPERATORS
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RUST PREVENTION
(Tanks, Pipe Lines, Submerged Metal)
Activated Alum Corp., Curtis Bay, Baltimore, Md.
The Barrett Co., 40 Rector St., New York City, N. Y.
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
(Cathodic Protection)
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Rusta Restor Corp., 1480 W. State St., Fremont, Ohio.
Wailes Dove - Hermiston Corp., Westfield, N. J.

SADDLES, PIPE
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Mueller Co., Decatur, Ill.

SAMPLERS AND SAMPLING TABLES
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Proudman & Goossen, New Canaan, Conn.
Roberts Filter Mfg. Co., Darby, Pa.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SAND EXPANSION INDICATORS
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

SCALE PREVENTION CHEMICALS
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.

SCREENS, INTAKE
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SCREENS, WATER WELL
Layne & Bowler, Inc., Memphis, Tenn.

SERVICE BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

SEWAGE DISPOSAL FLOOR SYSTEM
Ayer-McCarel-Reagan Clay Co., Brazil, Ind.
Bowerston Shale Co., Bowerston, Ohio.

SEWAGE EJECTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

SEWAGE SAMPLERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 325 W 25th Pl., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Proudman & Goossen, New Canaan, Conn.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SEWAGE SCREENING GRINDERS
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR
Dorr Co., 570 Lexington Ave., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

SEWER CLEANERS
Champion Corp., Hammond, Ind.
Petersen Hydraulic Flusher Co., 617 S. Sixth St., Milwaukee, Wis.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER DESIGN—CONCRETE
(Literature, Information, Advice)
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

SEWER PIPE
(See Pipe, Sewer)

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6061 W. 65th St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER RODS
Champion Corp., Hammond, Ind.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SHEETING
Armo Drainage Products Assn., Middletown, Ohio.

SIGHT FEEDERS
(For Chemical Pumps)
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

SIGHT GLASSES
Corning Glass Works, Corning, N. Y.
(Pyrex Brand)

SIPHONS (SEWAGE)
Armco Drainage Products, Assn., Middletown, Ohio.
Ralph B. Carter Co., 53 Park Place, New York City. (Alternating.)
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, PIPE REPAIR
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (VALVE)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SLUDGE DEWATERING
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.

SLUDGE DISINTEGRATORS
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE FILTERS (VACUUM)
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.

SLUDGE PUMPS
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SODA ASH
Diamond Alkali Co., Pittsburgh, Pa.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Michigan Alkali Co., 60 E. 42nd St., New York City.

Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM METAPHOSPHATE (GLASS)
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.

SODIUM SILICATE
Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York City.
Philadelphia Quartz Co., 124 S. Third St., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Co.
Tamms Silica Co., 228 N. LaSalle St., Chicago, Ill.

SOFTENERS AND PURIFIERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Calgon, Inc., 300 Ross St., Pittsburgh,, Pa.
Cloroben Corp., 225 Mercer St., Jersey City, N. J.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

SPEED REDUCERS, TRANSMISSION
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SPRINKLING FILTER PLANTS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

STACKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STACKS, FUME
Johns-Manville, 22 E. 40th St., New York City.

STANDPIPE AND TANKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STANDPIPE PRESERVATION
(Cathodic Protection Process)
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

STIRRERS (LABORATORY)
Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.

STOKERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

STORAGE TANKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STRAINERS, SUCTION
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA
Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

SULPHUR DIOXIDE (LIQUID)
Virginia Smelting Co., 131 State St., Boston, Mass.

SUPER-CHLORINATION UNITS
(See Chlorinators)

SWIMMING POOL EQUIPMENT
Activated Alum Corp., Curtis Bay, Baltimore, Md.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Ralph B. Carter Co., 53 Park Place, New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SWIMMING POOL TESTING OUTFITS (pH and Chlorine)
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Phippa & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SWITCHES, FLOAT, TRANSFER AND REMOTE CONTROL
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

TANKS, ELEVATED STEEL
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANK PRESERVATION
(Cathodic Protection Process)
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

TANK ROOFS—CONCRETE Z—D
Roberts & Schaefer Co., 307 N Michigan Ave., Chicago, Ill.

TANKS, RUBBER LINED
Atlas Mineral Products Co., Mertztown, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

TANKS, STEEL
(See Tanks, Elevated Steel)

TAPPING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

TASTE & ODOR CONTROL GRAPHS
Darco Corp., 60 E. 42nd St., New York City.

TASTE & ODOR REMOVAL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., 551 Fifth Ave., New York City.
Cloroben Corp., 225 Mercer St., Jersey City, N. J.
Darco Corp., 60 E. 42nd St., New York City.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

TESTERS, WATER METER
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Division of Pittsburgh Equitable Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St. New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

THICKENERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TOOLS, PNEUMATIC
Schramm, Inc., Westchester, Pa.

TOOLS, PORTABLE ELECTRIC
Syntron Co., Homer City, Pa.

TOOLS, SPECIAL
Benton Tool Corp., 426 Engineers Bldg., Cleveland, Ohio.

TRAPS, DRIP, FLAME, SEDIMENT
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TREADS, SAFETY
Arrowhead Iron Works, Kansas City, Mo.

TRICKLING FILTERS, HIGH RATE, HIGH CAPACITY
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Lakeside Engrg. Co., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TRITURATORS
(See also Grinders)
Chain Belt Co., Milwaukee, Wis.

TUNNEL LINER PLATES
Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING
The Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Jeffery Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES
Central Foundry Co., 386 Fourth Ave, New York City.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE BOX LOCATORS
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.

VALVES
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Rensselaer Valve Co., Troy, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.Y
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, CHECK
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.

VALVES, CONE, OF ALL TYPES
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, FLAP
Brown & Brown, Inc., 456 S. Main St., Lima, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, FOOT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MOTOR OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., 400 Ross St., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.

VALVES, PUMP
Johns-Manville, 22 East 40th St., New York City.

VALVES, RELIEF
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St., & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.

VALVES, SPECIAL AUTOMATIC
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

VENTURI TUBES
Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia.

VIBRATORS, ELECTRO-MAGNETIC
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., Homer City, Pa.

WASTE GAS BURNERS
Ralph B. Carter Co., 53 Park Place, New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Cochrane Corp., 17th St., & Allegheny Ave., Philadelphia, Pa.
Corning Glass Wks., Corning, N. Y.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.
Wilson Chemical Feeders, 110 Washington St., Buffalo, N. Y.

WATER HAMMER ARRESTERS
Water Hammer Arrester Corp., 12th and West Pierce Sts., Milwaukee, Wis.

WATER LEAK, LOCATING INSTRUMENTS
Northrop & Co., Inc., 50 Church St., New York City.
Pitometer Co., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Water Leak Detector Co., 166 N. Third St., Columbus, Ohio.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Electric Indicator Corp., P. O. Box 476, Stamford, Conn.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER MAIN CLEANING
Activated Alum Corp., Curtis Bay, Baltimore, Md.
National Water Main Cleaning Co., 50 Church St., New York City.

WATERPROOF CANVAS
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Asphalt Products Co., Inc., Syracuse, N. Y.
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chem Co., Merchants Bank Bldg., Indianapolis, Ind.
Sherwood Waterproofing Corp., 53 Park Pl., New York City.
Wailes Dove-Hermiston Corp., Westfield, N. J.

WATER SOFTENING CHEMICALS AND COMPOUNDS
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Permutit Co., 330 W. 42nd St., New York City.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER SOFTENING EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Calgon, Inc., 300 Ross Ave., Pittsburgh, Pa.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago (lime-soda).
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Syntron Co., Homer City, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeder, Inc., 110 Washington St., Buffalo, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York City.

WATER STABILIZATION
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Ozark Chemical Co., Tulsa, Okla.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

WATER TREATMENT FOR SCALE AND CORROSION
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.

WATER WASTE SURVEYS
Aqua Survey & Instrument Co., 1403 Marlowe Ave., Cincinnati, Ohio.
Pitometer Co., 50 Church St., New York City.

WEATHER INSTRUMENTS
M. C. Stewart, Ashburnham, Mass.

WEATHERPROOF PAINTS, ROOF COATINGS
Asphalt Products Co., Inc., Syracuse, N. Y.
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Road, Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Johns-Manville, 22 E. 40th St., New York City.
Quigley Co., Inc., 56 W. 45th St., New York City.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
Sherwood Waterproofing Corp., 53 Park Pl., New York City.

WEIGH FEEDER MACHINES
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Merrick Scale Mfg. Co., 180 Autumn St., Passaic, N. J.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Syntron Co., Homer City, Pa.

WELL WATER SUPPLY SYSTEMS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

WIND VANES
M. C. Stewart, Ashburnham, Mass.

WRAPPING, PIPE
(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET
Greene, Tweed & Co., Bronx Blvd. at 238th St., New York City.

ZEOLITE AND ZEOLITE SOFTENERS
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York City.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS

(WHERE TO FIND IT)

By LINN H. ENSLOW
Editor, "Water Works and Sewerage"

IT goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manuals published by the American Water Works Association—"Water Works Practice," the "Purification Manual and the "Accounting Manual."

Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference works for water and sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists called on to offer suggestions in making up a set of reference works. It is an attempt to recommend those books of greatest usefulness.

LIST NO. 1 —FOR WATER WORKS MANAGERS AND OPERATORS
[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
Water Works Practice—Manual of the A. W. W. A. ($5.00)	Williams & Wilkins, Baltimore	Various
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Manual of Water Quality and Treatment	Am. Water Works Assn., New York City	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md.	Hopkins
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A. and A. W. W. A., New York City	Various
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 2nd Edition ($2.50)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Copper Sulphate in Control of Micro Organisms (F)	Nichols Copper Co., New York City	Hale
Pump Data (F)	Economy Pumping Mach. Co., Chicago	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Chlorination of Water	John Wiley & Sons, New York City****	Race
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Handbook on Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies—4th Ed. ($6.00)	John Wiley & Sons, New York City	Turneau & Russell
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Water Supply & Treatment (F)	National Lime Assn., Washington, D. C.	Hoover
Treatment of Municipal and Industrial Waters—Tech. Bul. No. 8 (F)	The Solvay Process Co., New York City	
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md.	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md.	
"Hydro-tite" Booklet of Useful Information (F)	Hydraulic Development Corp., New York, N. Y.	
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracey
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan
Water Supply & Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
"The Hardy-Cross Method"—Bul. 286	Univ. of Illinois, Eng. Explt. Sta.	Hardy
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis.	

(F) Available as Free Publication at this writing.
****Out of print Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

Journals and Magazines (Applies to Lists 1 and 2)

Journal and Monographs of the American Waterworks Association
Journal of the New England Water Works Association.
Current Water Works Technical Magazines and Trade Papers.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman
Design of Dams ($5.00)	McGraw-Hill Boook Co., New York City	Hanna and Kennedy
Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
pH and Its Practical Application ($3.50	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion (nominal)	Carnegie Steel Corp., New York City	
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	*Nash*
Census of Munic. Water Purification Plants (nominal)	Am. Water Works Assn., New York City	
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Census of Municipal Water Purification Plants (50c)	Am. Water Wks. Assn., New York City	
Index to Jour. of A. W. W. A.—1881-1933 ($2.50)	Am. Water Wks. Assn., New York City	

****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

For Journals see list No. 1.

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Operation and Control of Sewage Treatment Plants (F)	New York State Dept. Health	N. Y. State Dept. Health
Sewage Treatment ($3.00)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Manual of Sewage Works Operation (nominal)	New Jersey Sewage Expt. Sta., New Brunswick, N. J.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J., and The Chlorine Inst., N. Y. C.	
Chlorination in Sewage Treatment (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.
Laboratory Manual of Water and Sewage Analysis ($2.50)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various
Sewage Works Journal—(Official publication of the Federation of Sewage Wks. Assns.)		
Current Sewerage Magazines		

LIST NO. 4—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**

(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	
Sewerage and Sewage Treatment—5th Ed. ($5.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Modern Sewage Disposal ($3.50)	Federation of Sewage Works Assns., New York City	Various
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees

(F) Available as Free Publication at this writing.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

***Note*—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

CENTRIFUGAL PUMPS*

Some Notes on Selection of the Proper Pump and A Simple Method of Checking Pump Efficiencies

By H. E. BECKWITH, Engineer
The Pitometer Company
New York, N. Y.

SOME twenty years ago when I first entered the water works field steam driven displacement type pumps were in general use. But, today we find the great majority of pumping stations equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage" Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

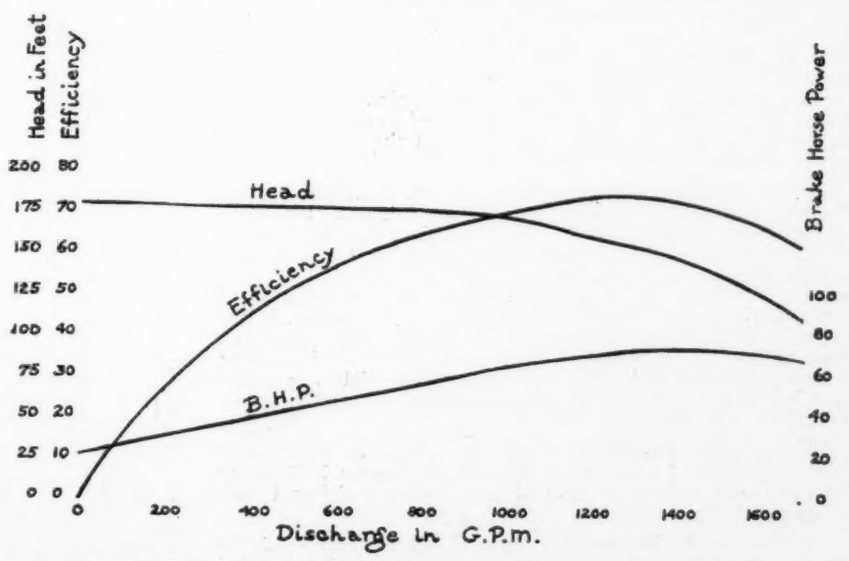
Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75%) is secured when the head is about 155 ft. and the discharge rate is about 1,300 G.P.M. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16" main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 G.P.M. and the efficiency to 70%. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

* Excerpts from a paper presented before the Penna. Water Operators Association and an earlier article by Mr. Beckwith in previous Reference & Data Issues of this magazine.

it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 G.P.M. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70% is much below the maximum efficiency of 75%. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5%) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 G.P.M. to zero G.P.M. Moreover an increase of only 3 ft. in head would cause a drop of 200 G.P.M. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 G.P.M. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the curve less than is customary a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 G.P.M. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump much more than 1,300 G.P.M. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40%. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 R.P.M. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 R.P.M. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 M.G.D. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 M.G.D. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 M.G.D. but the *efficiency decreased* to the point where it was only slightly above 40%. New and properly designed equipment brought the wire-to-water efficiency up to about 75%.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absolutely worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,007	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	684
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,493	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

when we found a water snake wrapped around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20% was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as th result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20% high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8%. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100% efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one KW.H. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance, the value at 150 ft. would be $\frac{318{,}200}{159} = 2{,}002$ gallons per KW.H. In this connection the accompanying "Table of Theoretical Values for Various Heads" may prove helpful in reducing calculations in pump testing. It was prepared by the writer and has appeared in earlier Reference and Data Numbers of WATER WORKS AND SEWERAGE.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per KWH by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the KWH consumed. This gives the gallons actually pumped per KWH.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100% pumpage per KWH. (Or take the figure from Table 1.) Next divide the actual gallons per KWH by the theoretical gallons per KWH to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 KWH. Say the total head noted was 220 ft. Dividing 32,640.000 by 30,200 gives an actual pumpage of 1,081 gallons per KWH. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per KWH at 100% efficiency (see table). Then;

$$\frac{1{,}081 \text{ (observed)}}{1{,}477 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction, in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0 K.W.	
Rate of discharge	51,840 gals. per hr.	
Delivery per KWH	572 gals.	
Pressure	146 lbs. =	337 ft.
Suction	15 ins. =	17 ft.
Difference in gauge elevation	1 ft. =	1 ft.
Total head		355 ft.

Theoretical discharge at 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gals.

and

Overall efficiency (wire-to-water) is $\left(\frac{572}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity G.P.M.	Efficiencies Percent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps. You may be surprised.

If an old 1,000 gpm pump, operating at an efficiency of 57%, is replaced with a new pump giving an overall efficiency of 73%

the same amount of water may be pumped with 22% less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22%. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per KWH to be expected at any head, for any efficiency, it is only necessary ot determine theoretical gallons per KWH for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per KWH the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important (if not more so) than is the total KWH consumption in determining the power bill to be expected from a new installation.

A Worthy Example

In the March, 1939, issue of WATER WORKS AND SEWERAGE an article by Messrs. Marshall and Rawlins of Charlotte, N. C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient) pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table I has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the sam period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table I indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,260,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

TERMINOLOGY IN PUMPING*

Static Head

Static Head is the vertical distance in feet between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head. is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump. plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

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3812 Castellar St., Omaha, Neb.
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THE NATIONAL METHOD

THE METHOD

The National Method of water main cleaning consists of passing a machine through the main which removes tubercles, incrustations and deposits from the pipe lining. This machine is either water-propelled or cable-drawn through the water main. Thorough cleaning can be accomplished by this method at the rate of approximately 50 to 100 ft. per minute, in sections of from several hundred feet to several miles depending upon conditions.

Briefly, the method involves cutting the pipe in two places, for entry and exit of the cleaning machine, inserting the machine; placing a riser pipe at the exit through which first the muddy water and then the machine emerge; propelling the machine by pressure or by cables through the pipe; finally shutting off the water, removing the riser pipe, and reconnecting the main.

The total time required for shutoff of water in any district is five to seven hours. In an emergency, the pipe can be temporarily made up and service resumed. The work can be done at night if desired.

20" Main in a Midwest City Before Cleaning.

THE RESULTS

The National Method is guaranteed to restore the carrying capacity of pipe to at least 95 per cent of that of new main (The actual result is usually very close to 100 per cent.)
The National Method gives you:

1. **Greater delivery**
2. **Lower pumping costs**
3. **Reduced insurance rates**
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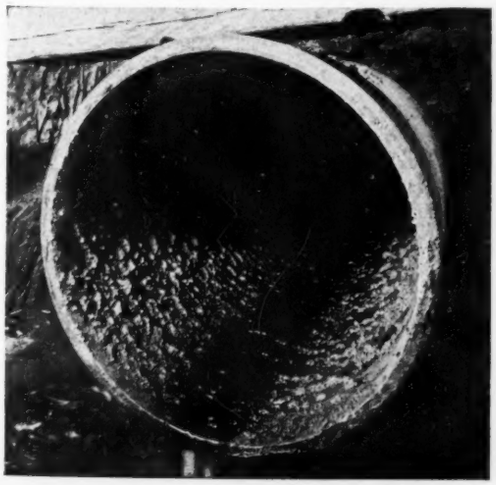
LET US CLEAN OUT YOUR CLOGGED MAINS

National experience makes satisfactory cleaning certain. National men know how to meet and overcome unforeseen difficulties that may arise.



When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.

Machine Arrives at End of Run After Cleaning 30" Main in St. Louis

Information regarding any of the hundreds of successful cleaning projects will be supplied upon request.

SPECIFIC SPEED CURVES*

Single Stage Centrifugal and Mixed Flow Pumps

IN 1932 a group of centrifugal pump manufacturers, members of the Hydraulic Institute, plotted curves representing the upper limits of specific speeds, in respect to head and dynamic suction lift, to which, according to their experience, centrifugal pumps may be applied with reasonable assurance of freedom from cavitation. These curves have proved valuable to users of pumps, as well as to the manufacturers. More recent experience and additional information have resulted in revisions:

The following examples illustrate the use of the new curves, here reproduced by courtesy of the Hydraulic Institute.*

Example I—Single-Suction Pump with Shaft Through Eye of Impeller

Given a total dynamic head of 100 feet and a dynamic suction lift of 15 feet, what is the safe upper limit of specific speed to avoid danger of cavitation?

Referring to the first chart (Fig. 1), the intersection of the diagonal for 15 feet suction lift with the horizontal line at total pump head of 100 feet, falls on the vertical line corresponding to 2250 specific speed on the scale at the top of the sheet. The specific speed should not exceed this value.

Example II—Double-Suction Pump

Given a total dynamic head of 100 feet and a dynamic suction lift of 15 feet, what is the safe upper limit of specific speed? Referring to the first chart (Fig. 1), the intersection of the

*Note:—These recently revised curves, which have been approved by all the leading pump manufacturers, are available in larger dimensions from the Hydraulic Institute, 90 West St., New York City, at a nominal charge.—Ed.

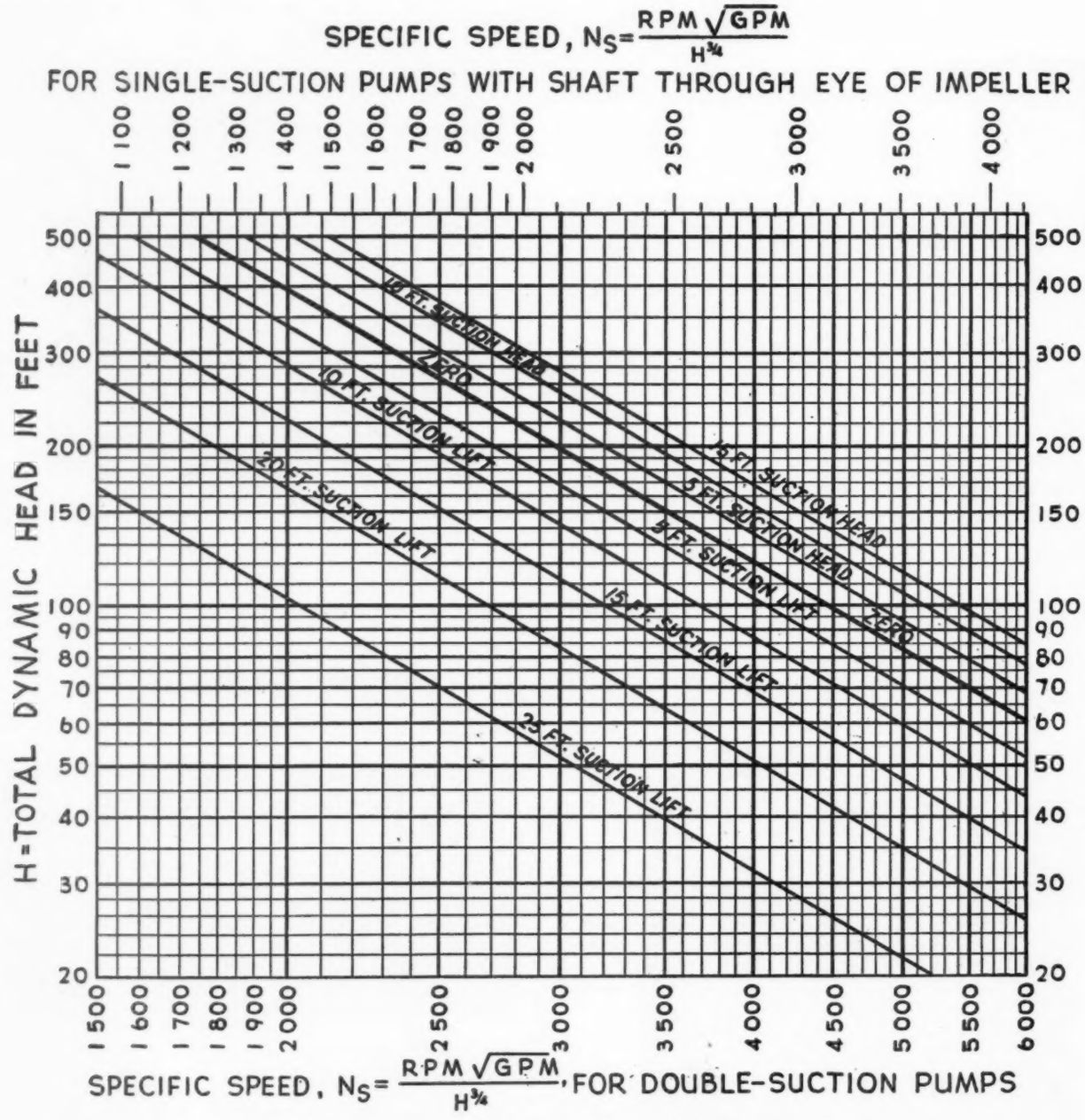


Fig. 1—Upper Limits of Specific Speeds for Single Stage Pumps.
(Pumping Clear Water at Sea Level at 85° F. For convenience, Values of H¾ for Various Heads Appear in Fig. 3.)

diagonal for 15 feet suction lift with the horizontal line for 100 feet total pump head, falls on the vertical line corresponding to 3200 specific speed on the scale at the bottom of the sheet. This is the value of $\frac{\text{rpm} \times \sqrt{\text{gpm}}}{H^{3/4}}$ in which the value of gpm is the

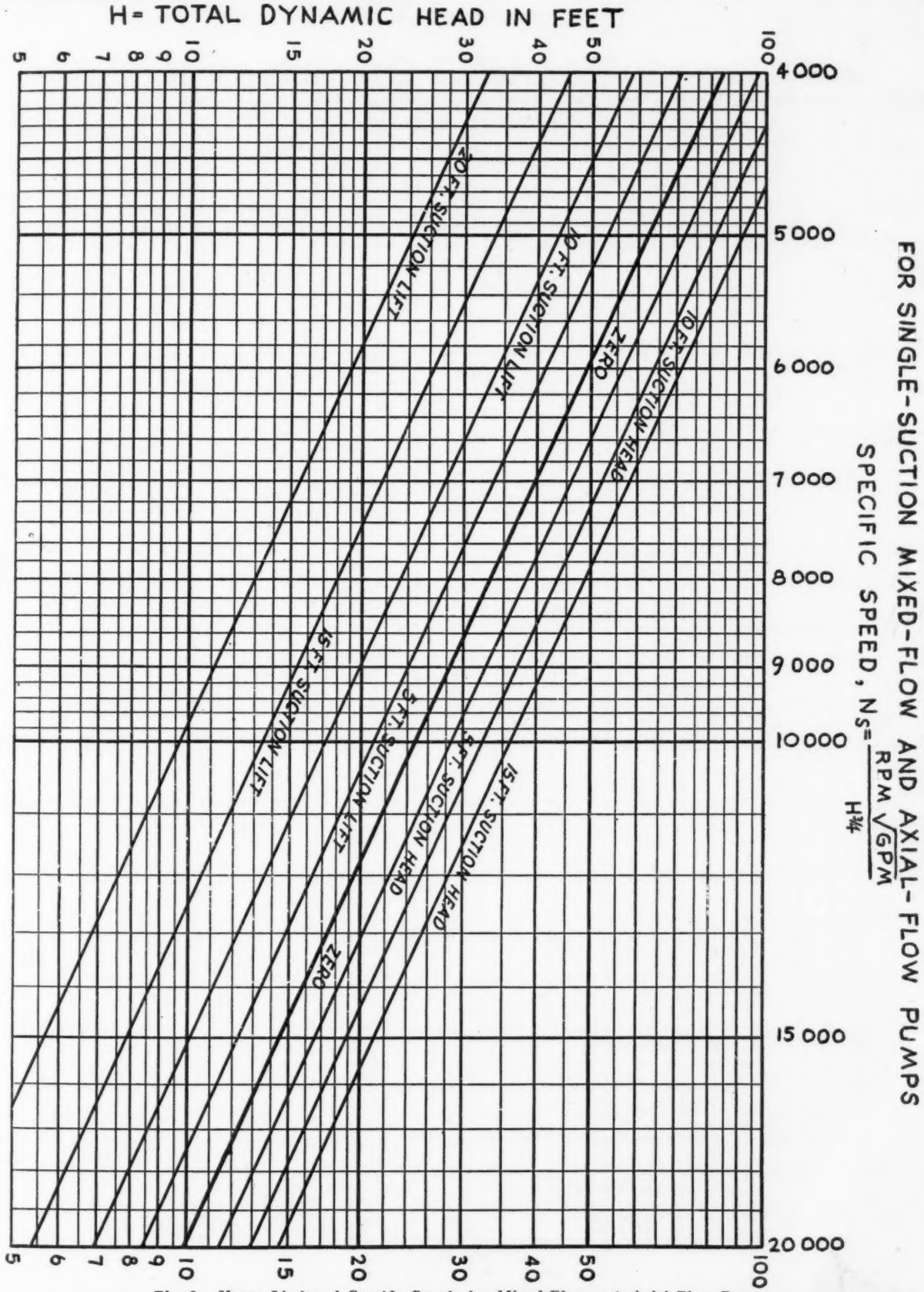


Fig. 2.—Upper Limits of Specific Speeds for Mixed-Flow and Axial-Flow Pumps. (Pumping Clear Water at Sea Level at 85° F.)

total gallons per minute capacity of the pumping unit including both suctions, and is the highest value which should be used for this head and suction lift.

Example III—Single-Suction Mixed-Flow or Axial-Flow Pump

Given a total dynamic head of 35 feet and positive dynamic suction head of 10 feet, corresponding to a submerged impeller, what is the safe upper limit of specific speed?

Referring to the second chart (Fig. 2), the intersection of the horizontal line for 35 feet total pump head and the diagonal for 10 feet suction head, falls on the vertical line corresponding to 9400 specific speed on the scale at the bottom of the sheet. The specific speed should not exceed this value.

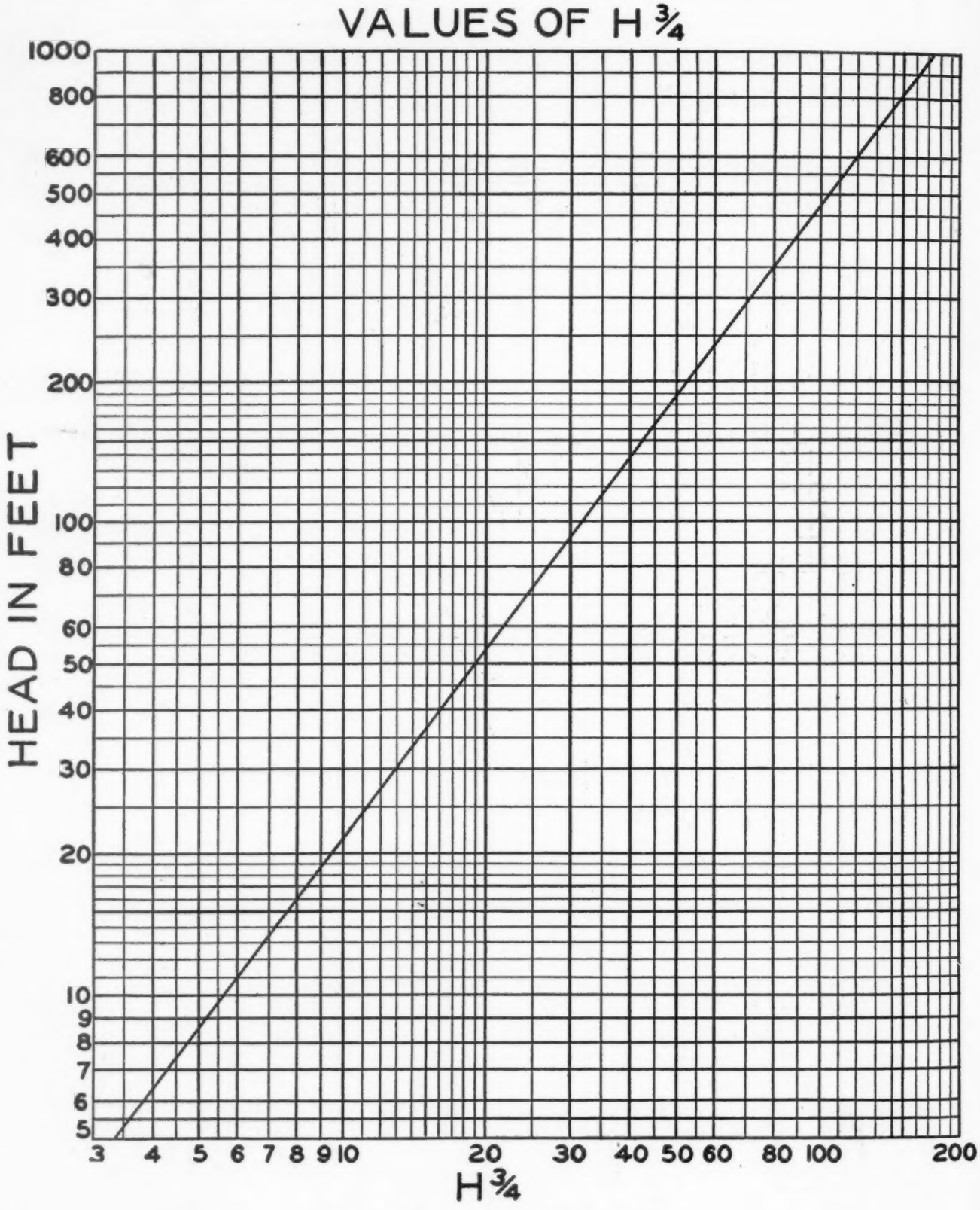


Fig. 3.—Values of H¾ for Various Heads.

SUBMERGENCE AND SPACING OF SUCTION BELLS

By C. A. RICHARDSON
Centrifugal Pump Engineer
Allis-Chalmers Mfg. Co., Milwaukee, Wis.

WHENEVER large centrifugal pumps are to be installed, the question of permissible submergence of suction bell and unit spacing always arises. This is as it should be, for the satisfactory operation of centrifugal pumps is largely dependent upon the suction conditions, and it is particularly important that careful consideration be given the suction conditions at the time the location and layout of suction bells are established.

On large waterworks or sewerage installations it is of prime importance that proper suction conditions are obtained.

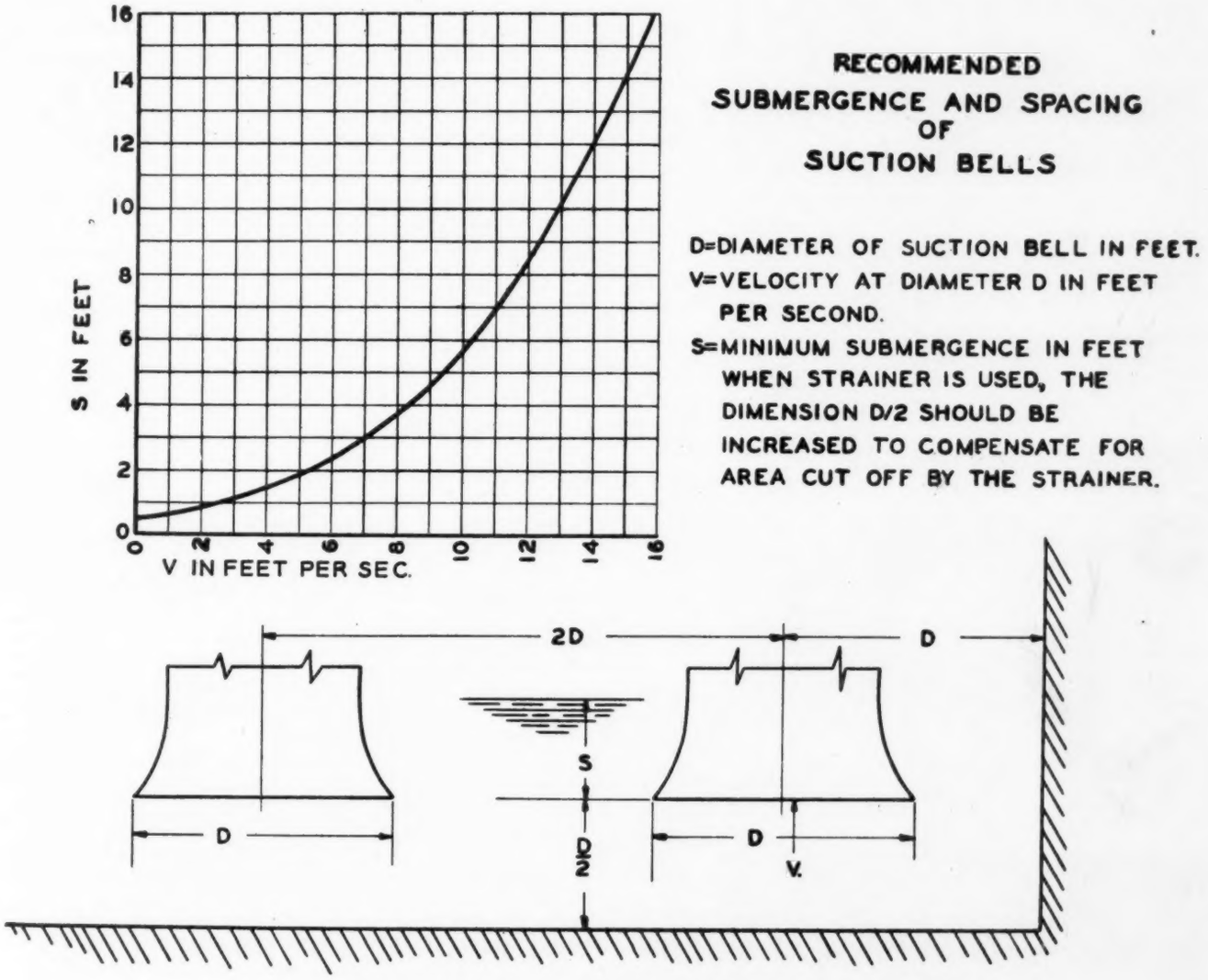
When laying out the location of suction bells careful consideration should be given to the following:

(1) Distance of suction from bottom of pit.
(2) Distance between suction bell and any obstruction.
(3) Distance between units.
(4) Minimum submergence of suction bell for maximum flow.

The accompanying diagram and curve shows the minimum relation of these factors recommended by the writer's company as representing good practice.

It is necessary that the flow in the region of the suction bell be free from vortices. Any change in direction of flow, will tend to form vortices, and it is important that ample space between any obstruction, such as columns, other suction bells, walls, etc., be allowed to permit dissipation of the vortex before reaching the suction bell entrance.

The amount of submergence required to prevent formation of vortices at suction bell entrances is largely dependent upon the entrance velocity. The accompanying curve gives the minimum suggested submergence. This curve is based on smooth non-turbulent flow into suction bell.



Recommended Submergence and Spacing of Suction Bells
(Developed by Allis-Chalmers Mfg. Co.)

SIMPLEX VALVE & METER COMPANY

6743 UPLAND ST., PHILADELPHIA, PA.

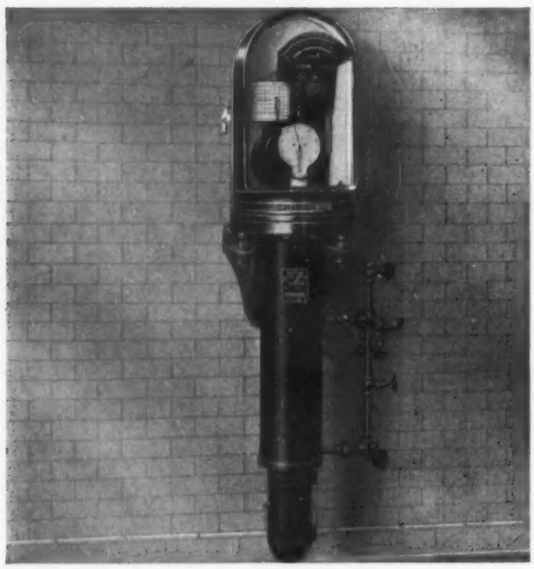
PRODUCTS

Simplex Venturi Type Meters for Measurement of Water, Sewage, Sewage-Sludge, and Air; Filter Rate of Flow Controllers; Loss of Head and Rate of Flo Gauges; Simplex Pump Casing Tap Meters; Pilot Tubes and Monometers; Portable Pitot Recorders; Water Level Gauges; Air Release and Air and Vacuum Valves; Proportional Chemical Feeding Devices; Hydraulic Equipment of Special Design; Sand Expansion Indicators, Summators, Air Differential Meters, Simplex Gyrometers.

ENGINEERING SERVICE

For over thirty-five years, Simplex Valve and Meter Company has been solving problems connected with metering and control which arise in waterworks and sewage plants. The benefit of this experience is yours for the asking and without obligation.

SIMPLEX METER REGISTERS

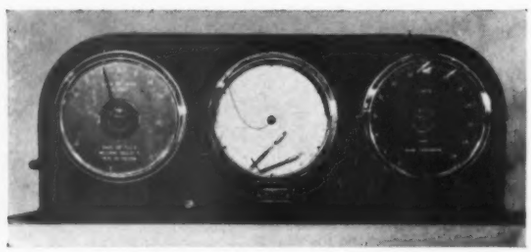


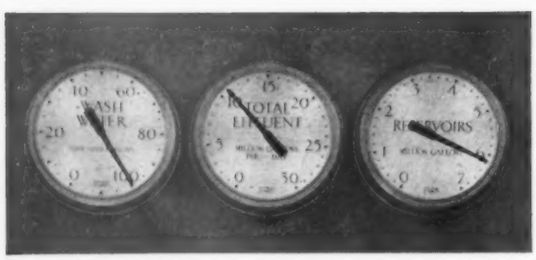
Simplex meter registers are designed for use in measuring liquors and gases under all pressure conditions and are particularly recommended for the measurement of raw water, wash water, filtered water, raw sewage, screened sewage, mixed liquor, raw sludge, digested sludge, and air. These meter registers are of the differential head type, designed for use with Venturi tubes, orifice plates, Simplex pitot tubes, on flow nozzles, weirs, or other forms of primary devices wherein a free-falling discharge is present and operating accurately on differential heads from ⅛″ up.

Simplex meters can be furnished for any metering problem, whether it be indicating, recording, totalizing, or any combination of these functions. Important improvements are embodied in the Air Differential Meter, the Simplex Gyrometer and the Summator models which are described in detail on the facing page.

Each instrument has included with it as a standard item of equipment a device whereby its accuracy and sensitivity can be checked at any time during its period of service.

SIMPLEX FILTER GAUGES





Furnished in any combination of indicating, recording, and totalizing rate of flow with indicating and recording of lost head, wash water rate or sand expansion.

Simplex gauges operate on the time tested Simplex float and mercury principle for the conversion of differential pressure heads into measurements of Loss of Head and Rate of Flow.

Standard Simplex gauges are furnished with floor stand or operating table mounting in a large choice of designs.

Similar in design with the Simplex meter register, Simplex filter gauges respond to the slightest variations in rate or loss, and will measure accurately over the entire range with an average error not exceeding ±3%.

Simplex rate of flow gauges have been arranged for totalization, wherein there is shown on a single 24″ diameter dial gauge, located on the operating floor, the total flow through any or all of the controller units. There can be mechanically linked to the total flow indicator, chemical feeders or chlorinators, thereby providing accurate control of the chemical dosage at all time during the plant run.

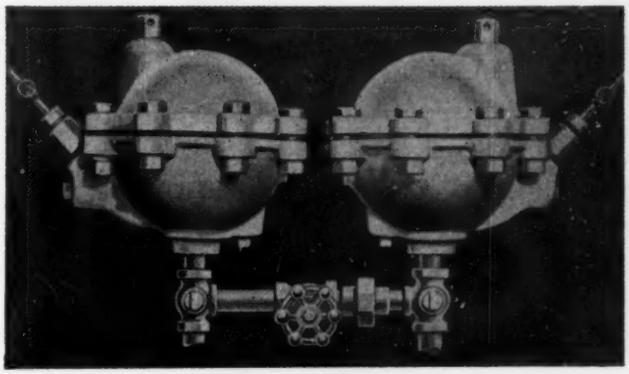
Illuminated display dial indicators are available for rate of flow of wash water, depth of wash water in tank, total filter discharge, pressure of wash water in manifolds, elevation of water in clear well or other basins, etc. These gauges are readable from both sides and arranged for roof or side wall installation. 30″ dials. Operated either by Simplex float chambers or electrically with Elinco motors.

Simplex water float gauges for measuring depth of water in clear wells, wash water tanks, sedimentation basins, etc., are available in either indicating or recording types.

SIMPLEX METERS FOR SPECIAL CONDITIONS

SIMPLEX AIR DIFFERENTIAL METER

For Remote Control Metering

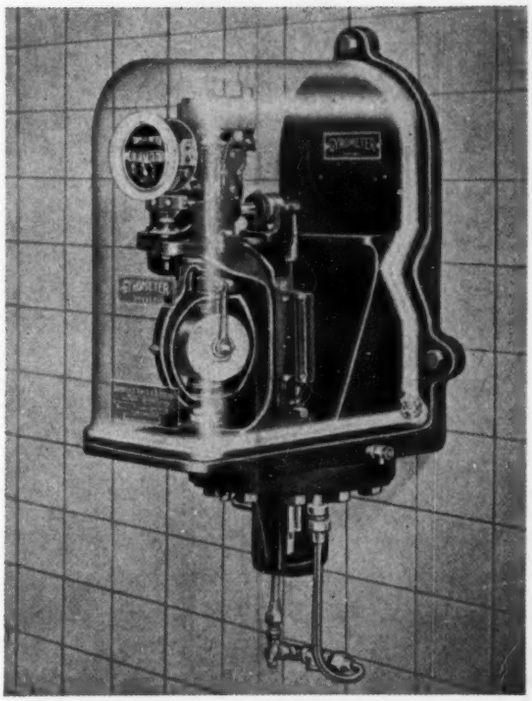


The Simplex Air Differential Meter provides two distinct improvements over the standard Simplex meter. *One:* the actuating force being air, the meter may be located without regard to hydraulic gradient and at an appreciable distance from the source of measurement; *Two:* corrosive liquids and those containing a high percentage of suspended and settleable solids can be measured without special designs and materials and without direct contact with the meter.

The Simplex Air Differential system can be used in conjunction with any form of primary device and any type of *Standard* indicating, recording or totalizing unit. It requires only the use of a small, continuous flow of air for its operation.

SIMPLEX GYROMETER

For Accuracy Over Wide Range of Flow



The Simplex totalizing gyrometer utilizes the force developed from a Gyroscopic couple in such a way that the departure of the flow law at low discharge rates, from the square root relation of the Venturi, with its decreasing coefficient; or of the Orifice, with its rising coefficient, is properly compensated. This provides accurate totalization over an extremely wide range of flow.

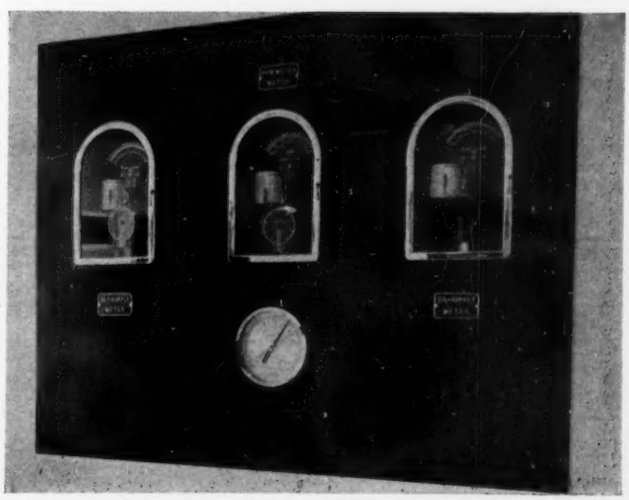
Further advantages result from the very slight diaphragm movement required to operate the gyroscope motor switch. This minimizes the flow of liquid through the pressure lines and so extends the usual limits of length of connecting piping and reduces its size. There is also an entire absence of accumulation of sediment in the instrument chamber.

The Simplex gyrometer will integrate the flow of any fluid, whether liquid or gaseous, in any size pipe containing either Venturi tube, Nozzle, Orifice, or Pitot tube, when located at any reasonable distance from the pipe.

The gyrometer may be actuated by the Simplex Air Differential System particularly for the measurement of liquids not suitable for pipes or meter chambers.

SIMPLEX SUMMATOR

A Master Meter to Combine Many Flow Rates



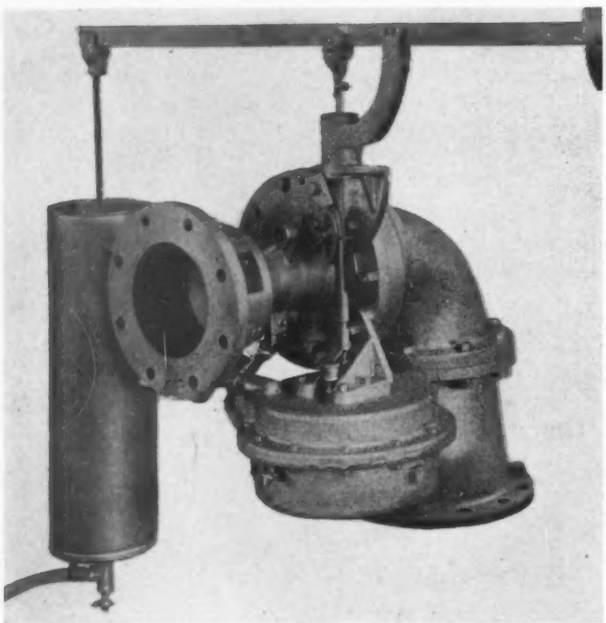
The Simplex summator is designed to totalize from two to twelve separate flow rates with extreme accuracy. It is sensitive to the slightest changes in flow rates of the individual meters, capable of easy and quick checking, and so constructed that a minimum of operating maintenance is required.

The actual summation is accomplished by mechanical and hydraulic means only with no lag or error being introduced into the system by electric circuits.

In addition to its service as a master meter, the summator is also used to operate accessory control, proportioning or feeding devices.

The Simplex summator can also be arranged to indicate the differences of individual flows or the ratios of any group of instruments and to operate any control device from these results.

SIMPLEX RATE OF FLOW CONTROLLERS FOR THE MODERN FILTER PLANT



SIMPLEX RATE OF FLOW CONTROLLER

For the Control of Flow Through Filters

The Simplex controller is a direct acting, balanced valve type operated by a Venturi tube located in the effluent line. Suitable for either gravity or pressure filters, it keeps the rates of flow through the filter bed at a constant rate regardless of variations in pressure or water level.

Simplex Controllers operate with the lowest obtainable head losses when wide open; attain the highest degree of accuracy in control without the use of compensating mechanisms; are capable of covering the largest possible ratio from maximum to minimum rates with any given size of unit; avoid the use of any electrical mechanisms in their operation; start quickly from a wide open position, and take the rate for which set in less than fifteen seconds.

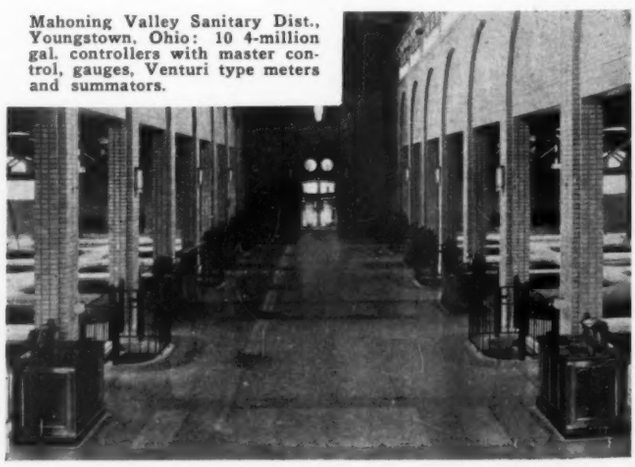
The control valve is located at the section of high velocity and so within the length of the Venturi tube making an extremely compact unit. The valve operating under greater head requires smaller and lighter valve parts, produces less friction, closer regulation, and a reduction in total weight. The outlet may be arranged for straight-through, right or left-hand as may be desired.

Simplex rate of flow controllers may be equipped with the Simplex master control system, whereby the rate through the entire battery of filter units can be changed from a single point on the operating floor or wherein the rate through each controller unit will vary with the elevation of water on the filter or in the clear-well. They can also be arranged with means for changing the rate of flow from the operating floor.

CLEAR-WELL CONTROL

Simplex controllers may be conveniently adapted to various types of clear-well control: the rate controller may be shut down automatically at a predetermined high clear-well level, opening up to its set rate as the level drops; total filtered discharge is made to balance the pumping demand on the clear water reservoir—this is accomplished by utilizing the Simplex fluid counterweight system (illustrated at the left) whereby the change in clear-well level controls the filter rate through the weight of water in the fluid counterweights acting on the controller scale beams.

Detroit, Michigan: Springwells Filter Plant—64 4-million gal. Simplex controller units with master control.



Mahoning Valley Sanitary Dist., Youngstown, Ohio: 10 4-million gal. controllers with master control, gauges, Venturi type meters and summators.

TABLE OR MASTER CONTROL

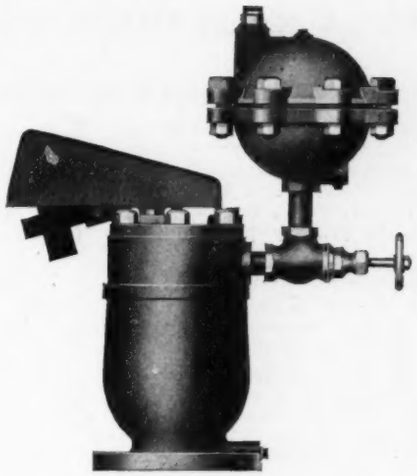
Table or master control is accomplished by filling or emptying the fluid counterweight by valves operated from one central point. This arrangement permits prompt changes in rate to meet a change in demand and is particularly advantageous where there is a large number of rate controllers in a gallery, small clear-well capacity, and wide range of demand on the plant.

SIMPLEX AIR RELEASE — AIR — VACUUM VALVES

Accumulations of air at high points in pressure pipe lines reduce the carrying capacity of the main or increase the frictional head because of the reduced cross-sections of the pipe at the summits.

Simplex air release valves automatically remove such accumulations with a minimum of maintenance. Twenty-five years of service prove that these valves possess the merits of continuous operation without attention, simplicity, compactness, accessibility, and low cost.

The Simplex air release valve consists of a cast iron hemispherical shell housing the lever, needle valve and glass float — all of non-rusting materials. Standard valves are furnished for pressures up to 400 pounds per square inch. Type ARA valves are supplied for pressures from 500 to 1250 pounds per square inch.



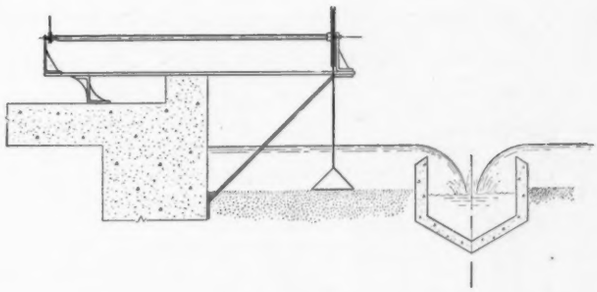
Special Applications:

1. *For Sewage Lines*—the type AGF valve has been designed for use on pressure sewer or sludge mains. A special pipe connection joins the valve to a riser pipe from the main. Arrangement is made for flushing the valve which only is required every few months.
2. *For Pump Casings*—a release valve with vacuum holding attachment placed close to pumping unit releases excess air and prevents pump from becoming air bound.
3. *Release Valves for Oil and Gasoline Lines*—special air release valves are available for removing air from oil and gasoline lines, also from lines carrying corrosive liquids.

SIMPLEX SAND EXPANSION GAUGE

A device for accurately determining the proper washing cycle for each filter bed. The resulting benefits include:

1. Reduced cost of washing by maintaining a standardized degree of sand expansion;
2. Formation of mud balls and sand cracks are eliminated because of washing at point of maximum expansion;
3. Attainment of greater standardization of washing;
4. Greater operating efficiencies resulting from higher filter runs with less wash water requirements;
5. Material reduction in length of wash period with resultant saving in wash water;
6. Accurate determination of quantity and intensity of surface wash requirements.



TYPICAL INSTALLATION SAND EXPANSION FLOAT UNIT

SIMPLEX REPRESENTATIVES

ATLANTA, GA., W. D. Taulman (W. J. Houston), 179 Spring St., S.W.

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BOSTON, MASS., C. W. Baldwin, 230 Congress St.

CHARLOTTE, N. C., T. C. Heyward (A. B. LeClere), Independence Bldg.

CHICAGO, ILL., A. F. Barron, 59 E. Van Buren St.

CLEVELAND, OHIO, A. MacLachlan, 1740 E. 12th St.

DALLAS, TEXAS, L. E. Livingston, 3921 Purdue St.

DENVER, COLO., Denver Fire Clay Co., 2301 Blake St.

DETROIT, MICHIGAN, DuBois-Well Co., 2832 E. Grand Blvd.

EL PASO, TEXAS, Denver Fire Clay Co., 209 Mills Bldg.

KANSAS CITY, MO., J. J. Heinrikson, 3689 Jefferson St.

LOS ANGELES, CALIF., G. T. Luippold, 1930 Olympic Blvd.

LOUISVILLE, KY., R. M. Overstreet, 1317 South Fourth St.

MILWAUKEE, WIS., F. H. Dorner, P. O. Box 1000.

NEW ORLEANS, LA., A. C. Hays, 1415 Carondelet Bldg.

NEW YORK CITY, N. Y., W. K. Sowdon, 342 Madison Ave.

OMAHA, NEBRASKA, Municipal service & Supply Co. (N. R. Lovirien), 504 Baum Bldg.

PITTSBURGH, PA., J. F. Hallowell, 705 Columbia Bldg.

ROCHESTER, N. Y., A. W. Schuster, 1025 Granite Bldg.

SALT LAKE CITY, UTAH, Denver Fire Clay Co., 157 W. Second South St.

SALT LAKE CITY, UTAH, C. F. Painter, % Water Works Equipment Co., 149 W. Second South St.

SAN FRANCISCO, CALIF., Water Works Supply Co., 501 Howard St.

SEATTLE, WASHINGTON, H. D. Fowler, P. O. Box 3084.

TORONTO, CANADA, S. A. McWilliams, Simplex Valve & Meter Co. of Canada, Ltd., 60 Front St., West.

TULSA, OKLAHOMA, Thilenius Equipment Co., 303 E. 4th St.

CUBA, Daniel, Inc., Metropolitan Building 814, Habana.

HAWAII, W. A. Ramsay, Ltd., Fort and Queen Sts., Honolulu.

MEXICO, F. A. Zapata, Apartado Postal No. 99, Mexico, D. F., Mexico.

PUERTO RICO, Roberto Colon Machinery Manufacturing Co., Comercio Street 17-19, San Juan.

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

BOSTON NEW YORK PHILADELPHIA BUFFALO PITTSBURGH ERIE CINCINNATI ATLANTA DETROIT
CHICAGO MILWAUKEE ST. PAUL KANSAS CITY HOUSTON DENVER SAN FRANCISCO

BAILEY METER COMPANY LIMITED, Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

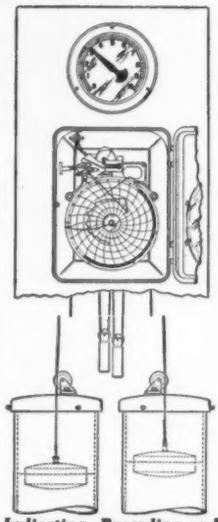
STANDARD BAILEY REGISTERS

Open Float Type Meters—The flow of sewage, sludge, dirty water or other liquids in pipe lines is accurately measured by the Bailey Float Type Meter using a Venturi Tube, flow nozzle or orifice as the primary producing device.

This meter is of the open float tube type with differential gearing and cam designed so that the register operates in direct proportion to the rate of flow.

Standard Bailey indicating, recording and integrating instruments are used; charts being 12" in diameter and uniformly graduated. These instruments may be either wall or panel mounted and may be furnished on self-supporting panels if desired.

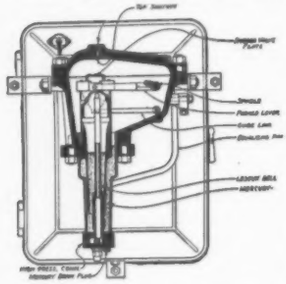
Bailey float type meters are simple, sturdy, neat-appearing and extremely flexible. Capacities may be changed by simple adjustments within the register and remote instruments can be operated from the main register if desired.



Indicating, Recording and Integrating open float tube type Register.

Bailey Flume Meters—Surprising low head losses result from the measurement of water or sewage in open channels when Bailey Flume Meters are used. These simple self-cleaning meters indicate, record and integrate on standard Bailey registers. Instruments may be placed in remote locations by the addition of the Bailey Synchro-Meter transmission system.

Bailey Weir Meter—Highly accurate results in the measurement of sewage or water flowing in open channels are obtained by the use of the Bailey Weir Meter.



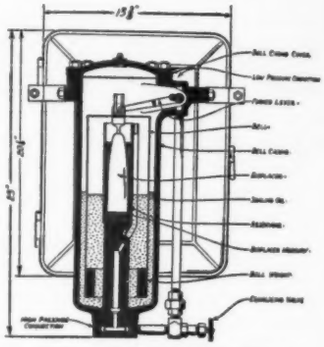
Section through flow mechanism of Ledoux Bell type Register.

Complete flexibility in the location of the standard Bailey registers of this meter may be provided by the Bailey Synchro-Meter transmission system.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey register previously described. Remote recorders may be provided by Bailey Synchro-Meter transmission which operates electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

Described in bulletin No. 301.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

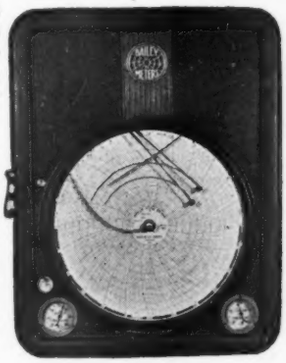
The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 8-in. of water. *Described in bulletin No.* 301.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible.



Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

MAIN-LINE METERING OF WATER, SEWAGE AND SLUDGE

By ROBERT T. REGESTER
Consulting Engineer, Baltimore, Md.

AN accurate and convenient means for metering the flow of water in main pipe lines presented an unsolved problem in early American hydraulic and water supply practice. It was not until 1887 that Clemens Herschel, eminent New England engineer, conceived the idea of applying the Venturi principle as a practical method of flow measurement. After conducting elaborate experiments, he invented and successfully calibrated a compound conical tube which he named the "Venturi meter." In 1891 the meter was first installed by the East Jersey Water Company. Its success was immediate and marked a notable contribution to hydraulic engineering. Twelve years later, the first Venturi meter for the measurement of sewage was installed in a large discharge pipe at the Ward Street Pumping Station of the Boston sewerage system. This installation was also successful and continues in operation today.

Since these first applications, continuous developments and improvements have been made in Venturi metering, particularly with regard to automatic registering and recording instruments. Today Venturi meters and their related devices are used throughout the world in both water works and sewerage systems for a variety of purposes. They are recognized as invaluable aids to the efficient operation and control of modern water purification plants and sewage treatment works. Although other metering elements are available, the Venturi meter is the universal standard for the measurement of water, sewage and sludge flowing through main pipe lines.

Venturi Tubes

A standard Venturi tube, as shown in Figure 1, comprises a cylindrical inlet, a converging inlet cone, an intermediate "throat" section and a diverging outlet cone. The inlet cone has a rather

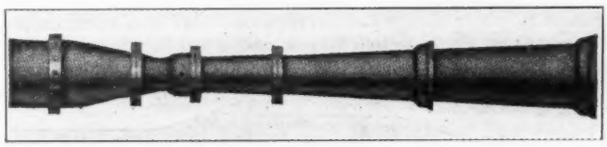


Fig. 1—The Herschel Standard Venturi Tube

steep taper while the outlet cone tapers more gradually. The interior passageway of the tube is entirely unobstructed. The sections of these tubes are usually made of cast iron with throat part bronze-lined to resist corrosion. The inlet and outlet cones are occasionally constructed of either reinforced concrete or steel plates. At both the inlet and the throat of each tube, an annular pressure chamber communicates with the interior by means of numerous small and equally-spaced vent holes. These annual chambers are basically important features of Venturi tubes. The essential purpose of each chamber is to average the pressure head at several points around the tube's circumference, thus avoiding the inaccuracies otherwise introduced by using a single-vent piezometer.

The favorable hydraulic properties of the standard Venturi tube are unequalled by any other type of metering device for main pipe lines. If piezometers are inserted along a standard Venturi tube, the hydraulic grade line will follow the curve as illustrated in Fig. 2. The velocity of flow rapidly accelerates from the inlet to the throat, and thereafter gradually decelerates through the outlet cone. Accordingly the pressure head which is greatest at the inlet end rapidly decreases to the throat where it is least. This difference in pressure bears a definite relation to the velocity of flow and therefore, the quantitative rate of flow. This function varies approximately as the square of the velocity in the throat. It should be particularly noted that the pressure is gradually regained as the velocity decreases in the outlet cone, until at the outlet end nearly all of the original pressure head has been restored. The overall pressure drop, or "friction loss," between the inlet and outlet ends is relatively small for normal rates of discharge, and for low rates it is negligible.

The size of a Venturi tube is expressed by the diameter of the inlet and outlet ends, in inches, which usually is the same nominal diameter as the pipe line for which the tube is intended. The standard tube of Herschel proportions has an average length of about nine inlet diameters, but the exact length depends upon the throat diameter. For installations where the conditions are favorable, shorter and somewhat less costly Venturi tubes are available. In general, these are similar in construction to the standard tubes, but have outlet cones of sharper taper with consequent greater friction loss. Certain special designs of tubes are also made, such as elliptical, constant-acceleration and flat-invert (or eccentric type). In instances where low points cannot be readily drained, or where overhead clearances are very limited, the flat-invert tube may be desirable. However, such tubes are considerably more costly than standard concentric tubes, which experience has demonstrated to be most suitable for normal installations.

For the measurement of sewage and sludge, Venturi tubes require certain special appurtenances. At the inlet and throat pressure chambers, vent-cleaning valves are necessary so that, at intervals, the vents can be cleaned of deposits and the pressure chambers flushed. An individual hand valve is often provided for each vent. However, a recent device (Fig. 3) is available for simultaneously actuating all of the vent-cleaning valves by the operation of a single water- or air-pressure supply valve. Hand holes near the inlet and the throat are useful for an occasional inspection of the interior surface of a tube. In cases where the sewage contains corrosive industrial wastes, a special split-flange section of tube can be provided to expose the entire throat part for examination and cleaning.

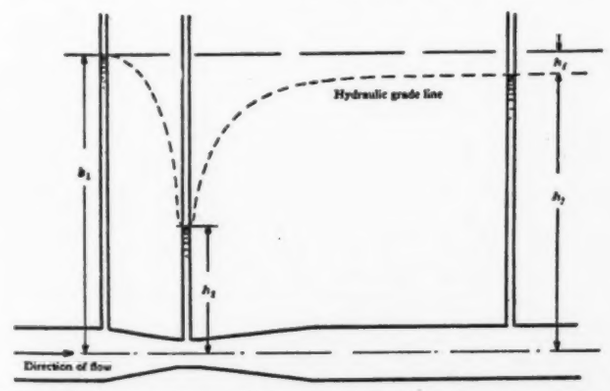


Fig. 2—Hydraulic Grade Line for Flow Through a Venturi Tube

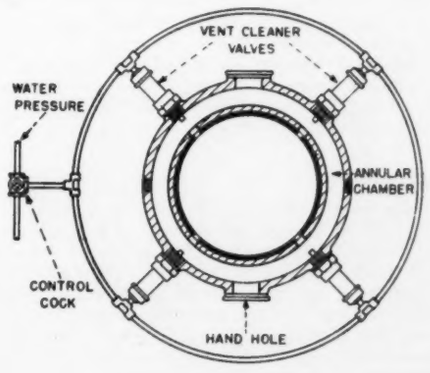


Fig. 3—Hydraulic Vent Cleaning Assembly for Simultaneous Operation

Other Types of Meters

Orifices and Nozzles

Among other types of meters available for main pipe lines are orifices and flow nozzles. Orifices can be obtained in several forms, the most familiar of which is a circular opening in a flat plate clamped between a pair of flanges in the pipe line. The hole of the orifice may be either concentric or eccentric in the flat-plate type. Piezometer connections are made on each side of the orifice plate by tapping two small tubes into the main pipe line. The differential pressure between the inlet and outlet sides of the plate is used to actuate the metering instrument. Orifice plate assemblies with annual pressure chambers, tapped for piezometer connections, are available.

The hydraulic grade line for a plate orifice is shown in Fig. 4. With flow through the main pipe, the pressure head drops abruptly at the orifice and continues to decrease slightly opposite the plane of greatest contraction just downstream from the plate. Beyond this plane the pressure then increases with partial recovery of the original pressure head. Because of the plate projection inside the pipe considerable turbulence results; hence the overall

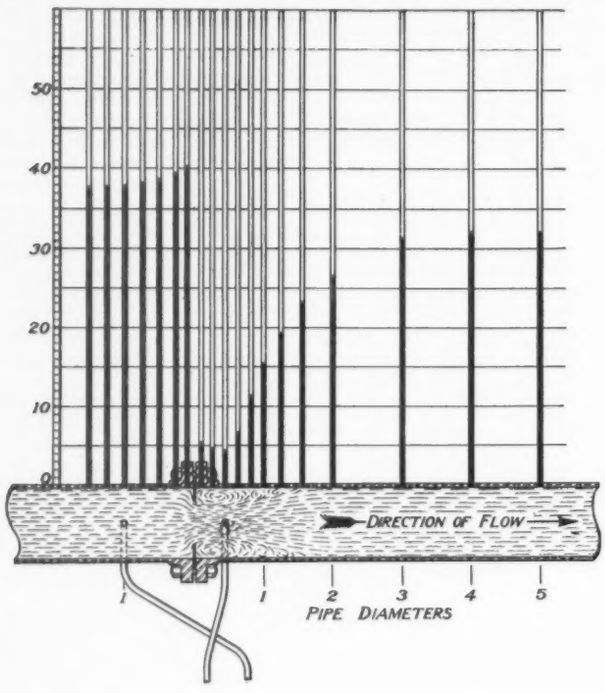


Fig. 4—Hydraulic Grade Line for Flow Through a Concrete Plate Orifice

friction loss for a given ratio of orifice and pipe diameters is much greater than for a Venturi tube having the same ratio of throat and inlet diameters.

If used for the measurement of sewage and sludge, plain orifice meters may be subject to inaccuracies resulting from erosion of the edge and accumulation of solid matter at the projection. Certain specially shaped orifices, or so-called "flow nozzles," resembling Venturi tubes can be furnished to overcome some of the disadvantages of the plate orifice.

The Kennison Nozzle

The Kennison open-flow nozzle is suitable for measuring flows of sewage, industrial wastes and sludge in partially filled pipes and open channels. This nozzle is bolted to the outlet end of a main pipe line with free discharge. The design utilizes the inlet depth produced by a specially shaped outlet for the rate-of-flow function which varies directly with the head. At the inlet of the nozzle, a connection is made to a float tube for operating the metering instrument, Fig. 5. Kennison nozzles are made in inlet sizes varying from 6 in. to 36 in. diameter. Another type of nozzle for partly filled pipes utilizes the discharge-angle relation, produced by a vane which receives the discharge impact, as the rate-of-flow function. This latter nozzle (Schofield) has a parabolic outlet.

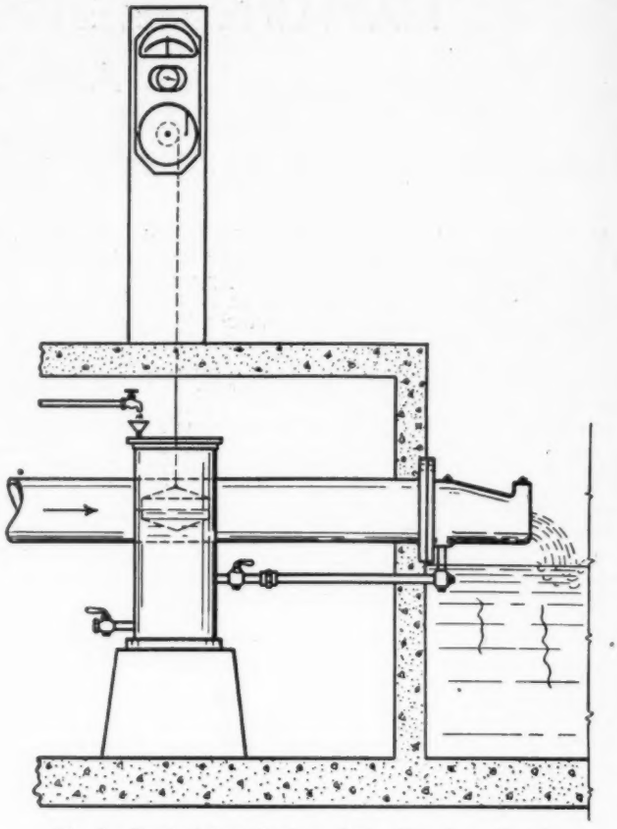


Fig. 5—Typical Installation of the Kennison Nozzle

The Parshall Flume

For the measurement of sewage flows in open channels, the Parshall flume is now extensively used. This Venturi shaped flume usually operates as a free-flow device and therefore requires the use of a single pressure head to accurately determine the discharge rate. The flume was originally developed and is widely used in the West for irrigation purposes. The first important installation for measuring sewage was at Providence, R. I., in 1931, where a large flume having a capacity of 120 M.g.d. with throat width of 10 ft. (Fig. 6) meters the effluent from the sewage treatment plant. An important characteristic of the Parshall flume is the relatively small loss of head, which is about one-fourth that of the standard weir for free flows. This flume is adaptable for both large and small plants and has been calibrated for a variety of sizes and corresponding capacities. A pipe connection is made on the tapering inlet side of the flume for the float actuation of a metering instrument.

Discharge Coefficients and Friction Losses

With any type of meter for main pipe lines, the accuracy of measurements must be supported by exact knowledge of the discharge coefficient and its relation to the size, ratio and other characteristics of the respective type. The accuracy of the Venturi meter has been established through numerous carefully conducted calibration tests by hydraulic laboratories and prominent manufacturers. Such tests have demonstrated that the high initial accuracy of the Venturi meter remains unimpaired during years of continuous service. Coefficient curves for standard Venturi tubes (as made by Builders Iron Foundry and the Simplex Valve & Meter Co.) are available in the A. S. M. E. —Fluid Meters Research Publication, Part I, 1937. In addition thereto, various types of upstream disturbances have been analyzed with regard to Venturi tubes and corrective vanes have been studied by Prof. W. S. Pardoe (Trans. A. S. M. E.—Nov., 1936, and Nov., 1937). Also, a valuable study of the proper application of piezometer connections to metering devices was made by Messrs. Allen and Hooper (Trans. A. S. M. E.—1931) as a further contribution toward meter accuracy.

The overall friction loss produced by a differential metering device in main pipe lines is frequently of economic importance. Such losses may substantially increase annual pumping costs, or may materially decrease the gravity head which is available for

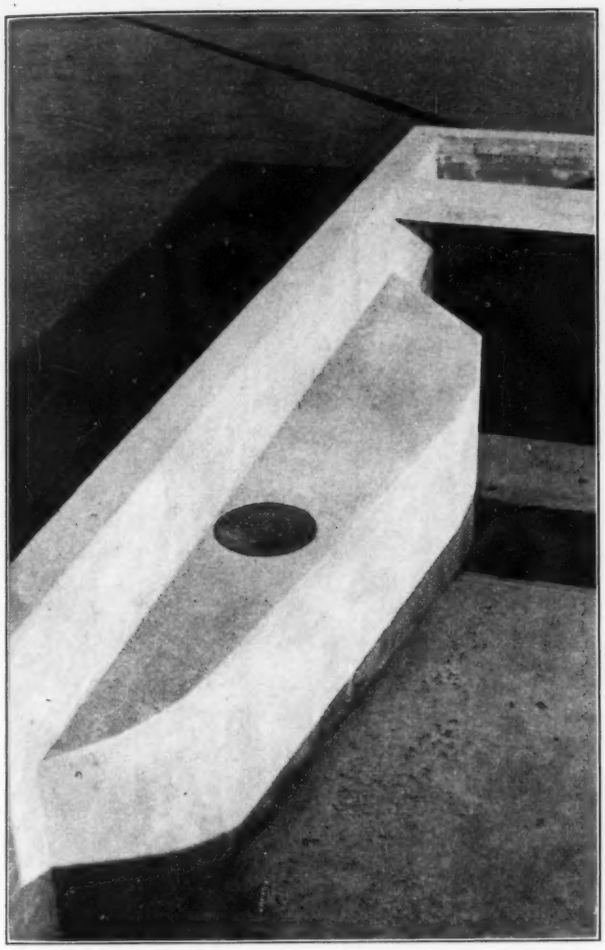


Fig. 6—One-Half of the Parshall Flume, Looking Downstream to Throat Section—Providence, R. I.

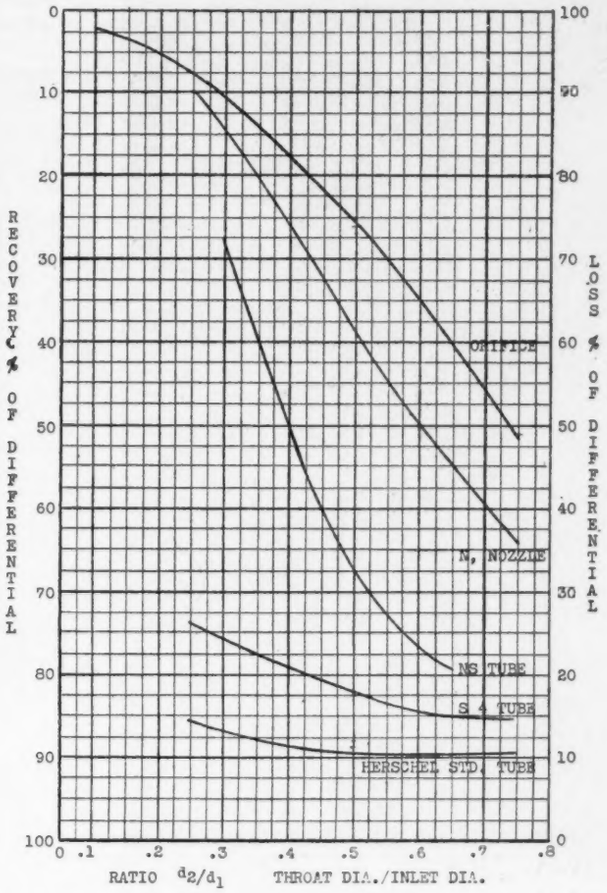


Fig 7—Recovery Characteristics and Friction Losses of Various Differential Producers

For Figs. 8 and 9, see next page.

other essential purposes in both water purification and sewage treatment plants. This latter condition may involve greater construction costs due to the lowering of structures to meet the resulting hydraulic grade lines. In either case, a small initial saving in the price of an unsuitable meter may be insignificant in comparsison with the ultimate cost incurred by excessive fraction loss. Accordingly, that metering device in which the recovery of inlet pressure head is the greatest will most likely prove to be the most economical selection.

The accompanying diagram, Fig. 7, strikingly presents a comparison of the recovery characteristics and friction losses for a standard Venturi tube of Herschel proportions, a short Venturi (S4) tube, two types of flow nozzles (NS and N) and an orifice plate. These data are expressed thereon as precentages of the differential head for various ratios of throat and inlet diameters. For the frequently used ratio—0.5, it should be noted particularly that the corresponding friction loss for an orifice is about seven times the loss for a Herschel standard tube.

Herschel standard Venturi tubes have a fraction loss of only 10% to 15% of the differential head for a ratio of 0.25 to 0.75—throat to inlet diameter. In comparison, the fraction loss for orifices is much greater and varies from 49% to 92% of the differential for the same ratio range of orifice opening to pipe diameter.

Venturi Metering Instruments

A variety of instruments for the measurement of water and sewage in connection with Venturi tubes and other differential metering devices is available. Each type is actuated by the differential head, either by direct connection or by some medium of transmission such as air or electricity. Several types of instruments are illustrated in Fig. 8 and 9. The mechanism of one prominent type is shown in Fig. 10. At the rear of the register two large mercury wells, connected at the bottom to form a U-tube, receive the differential pressure from the Venturi tube through small pipes from the inlet and the throat. One of the mercury columns supports a solid metal float of large diameter, which is responsive to minute variations in mercury levels. Through a positive rack and gear transmission, the float

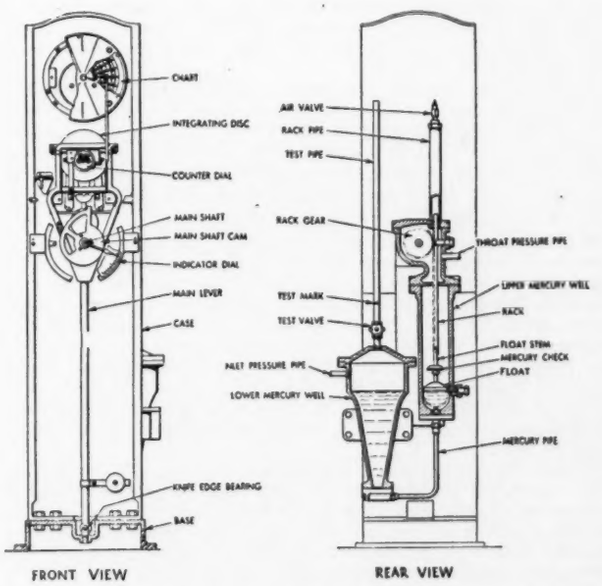


Fig. 10—One Example of the Pressure Chamber Type of Register Mechanism, with Rack and Gear Transmission of the Float Movement

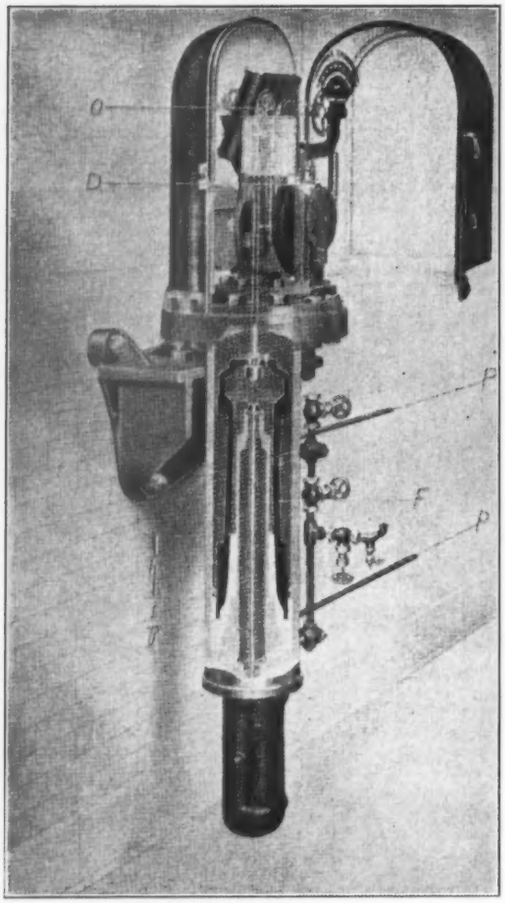


Fig. 8—Pressure Chamber Type of Instrument Using Mercury Sealed Bell (Courtesy of Simplex Valve & Meter Co.)

For Fig. 10, see preceding page.

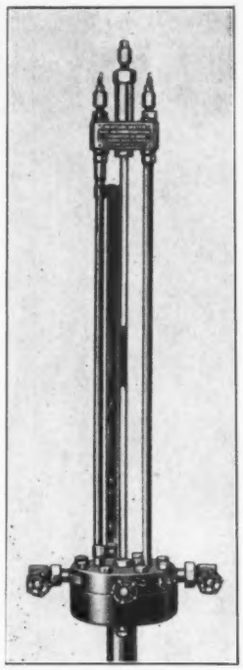


Fig. 11—Portable Flow-Rate Indicating Instrument of the Barometric Type

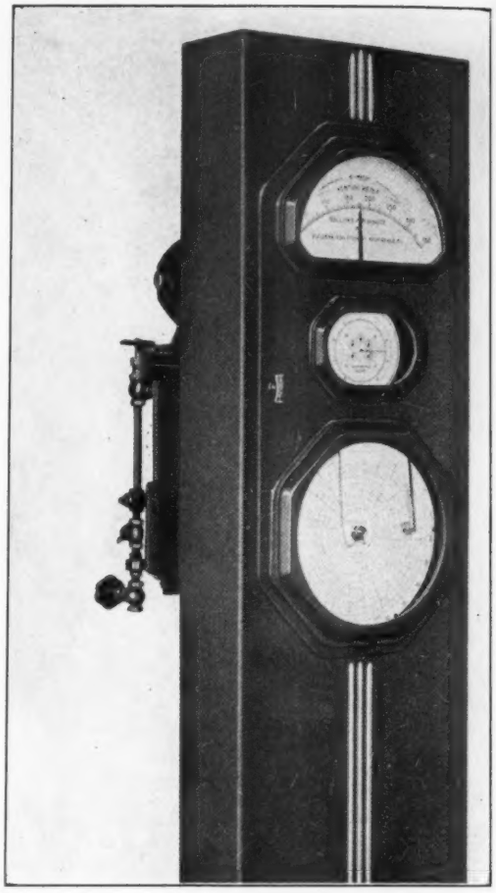


Fig. 9—Modern Register-Indicator-Recorder, with Pair of U-Tube Mercury Wells (Courtesy of Builders Iron Foundry)

movement establishes the position of the rate-of-flow indicating hand, the rate recording chart pen and the driving roller of the motor-driven totalizer. These are respectively the upper, lower and middle dials (Fig. 9).

A simple mechanical instrument, suitable for main pipes in small plants and for less important pipes in large plants, is very similar to the instrument shown in Fig. 13. This instrument can be used with either Venturi tubes or orifices for the measurement of water, sewage, sludge, air and other fluids. Principal features of this device are compact design, gear-driven integrator and universal mounting for floor, wall or panel.

A portable and sturdy flow-rate indicating instrument of the barometric type is shown in Fig. 11. The rate scale, 22 in. long, can be graduated to read directly in units of flow. The slightest change in rate through the Venturi tube, or other differential producer, will cause an immediate and relatively large response in the vertical movement of the mercury column within the single glass tube. In addition to this instrument, several types of manometers can be obtained for a variety of purposes. A double-tube type is especially suitable for general testing work. Graduations can be either in inches of deflection, or directly in rates of flow.

Where the conditions of installation make the use of mechanically actuated instruments impracticable, electrically-operated transmitters with receiving instruments can be employed for remote metering indications and recordings. Numerous types or systems have been developed such as time impulse, stepped resistance, self-synchronous motor pairs and others.

The time impulse system is used with Chronoflo transmitter and receiver instruments, Fig. 12 and 13. The transmitter receives the differential pressure, and is usually installed close to the Venturi tube or other differential device. It contains a mercury float, a synchronous motor-driven mechanism and a magnetic mercury switch. These elements are so interconnected that for a portion of each cycle (¼ to 1 minute), varying in duration in exact proportion to the rate of flow, electrical "time impulses" are sent to the distant receiving instrument. The latter, through motor-driven magnetic clutch elements, translates these impulses into flow units on the dial and chart.

Weather-proof instruments for installation out of doors are readily available with substantial weather-proof metal housings.

Metering instruments are logical sources of signal and control actions as related to flow rates. Lights, sound apparatus, power relay switches and other electrical elements can be readily actuated by such instruments at relatively small cost.

Methods of Installation

Two simple methods of installing Venturi tubes and instruments for the measurement of water are shown—Fig. 14. That for medium and high heads is on the left, and the method for low heads on the right. When the pressure is ten pounds or

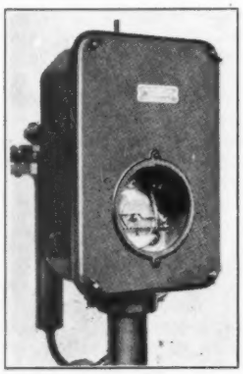


Fig. 12—Transmitting Unit

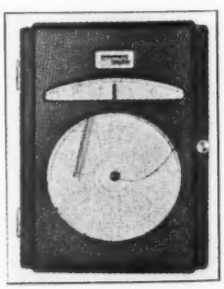


Fig. 13—Receiving Unit

Chronoflo Time-Impulse Instruments for Remote Metering (Courtesy of Builders Iron Foundry)

more at the floor where the instrument is located, two small pressure pipes—one from the inlet and the other from the throat of the tube—form a direct connection. These pipes can be several hundred feet in length. Where the acting hydraulic head is low (e.g. raw water supply to filter beds) the usual mercury wells at the back of the registering instrument are

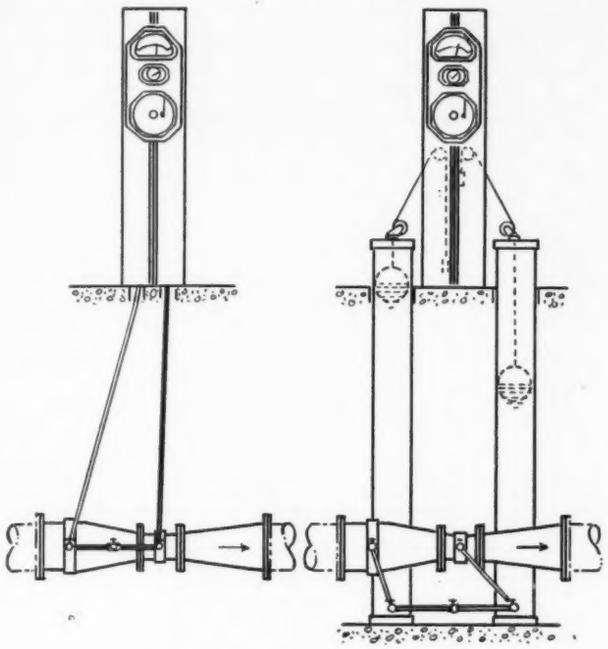


Fig. 14—*Venturi Meter Installations*
Left—For Medium and High Heads
Right—With Float Tubes for Low Heads

removed and vertical inlet and throat float tubes are substituted. Cables from these floats lead to a differential actuating mechanism at the back of the instrument.

Other types of installation require the mercury wells to be placed at a low elevation with a cable connection to the register above. With any of these types for the measurement of sewage and sludge, provision must be made for seals to prevent deposits from reaching the registering instrument through pressure connections, or for proper flushing with clean water. Such flushing may be either continuous or manually regulated, as the requirements dictate.

Air Relay System

The use of compressed air as a medium for the transmission of the inlet and throat pressures of a Venturi tube, or other differential producer, to a distant recording instrument is frequently advantageous. One type of "air relay system" employs two diaphragm units, one directly connected to the inlet and the other to the throat of the Venturi tube. Each unit consists (Fig. 15) of a hollow chamber (C) which is divided into two compartments by a solid rubber and fabric diaphragm (D). The inner side of the diaphragm is subjected to the liquid pressure from the tube; the outer side receives an external air pressure to balance the liquid pressure on the inner side. Air is continually vented through a throttled needle valve (N) attached to the diaphragm unit. Two small pipes, one from the inlet and the other from the throat relay unit, are connected from the outer compartments to the usual mercury wells at the rear of the registering instrument. The transmitted air pressures are exactly equal, respectively, to the actual inlet and throat pressure heads in the Venturi tube.

This type of unit forms a seal between the tube and the instrument, which is especially important in metering sewage and sludge. In the measurement of sludge, unless it is "thin," it is necessary to provide continuous water flushing through appropriate small sight-feed orifices.

Another well known type of air relay system operates with a single air pressure which is proportional to the amount of the liquid differential pressure.

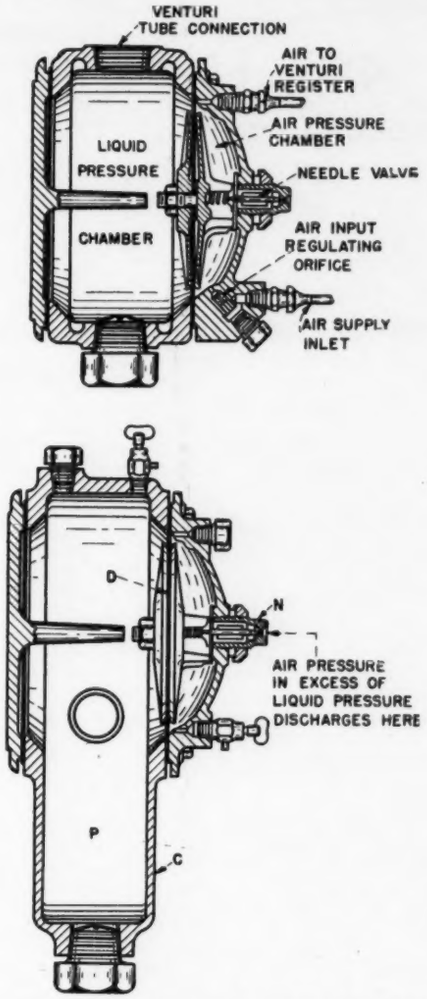


Fig. 15—*Diaphragm Unit for Air-Relay System*

Flow Summation

Recent developments make it possible to summarize, on a individual meters in their respective discharge pipes. It may be single instrument, the readings of several meters. For example, a water works pumping station may have several pumps with desirable to totalize these separate flow rates for purposes of accurately introducing chemicals, such as chlorine, without wastage. In this case, an electrical transmitter (such as Chronoflo) can be attached to each registering instrument (Fig. 16). The impulses sent out by these transmitters go to a master unit which integrates the respective values, and then transmits the total to distant summation indicating, recording and totalizing instruments, as required.

In sewerage districts and sewage treatment plants, the summation principle can be utilized to great advantage. Sewage flows from scattered communities can be summarized and transmitted to the central or joint treatment plant for the guidance of the operator, and for the allocation of operating charges. Likewise, flow divisions within a large sewage plant can be summarized for control purposes.

Means can also be provided to give the difference in readings for two meters, or the difference of the combined rates of flow in groups of meters.

Special Metering Instruments

The marked trend in recent years of centralized control in water purification and sewage treatment has been accompanied by a fulfilled demand for the broader performance of main pipeline meters. Distant transmission by air or electricity to centralized panels and control tables, the ratio of one flow to another, the summation of flows to one or more central dials, the automatic

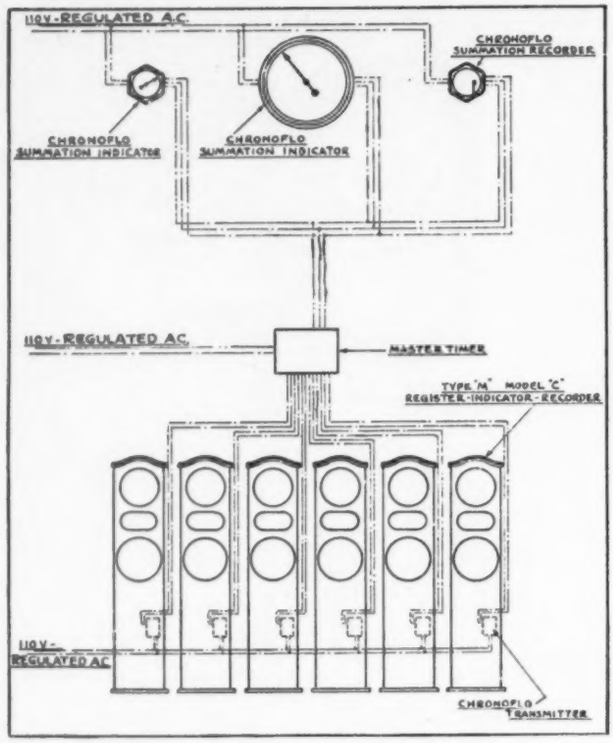


Fig. 16—Diagrammatic Arrangement of Flow Summation Instruments for Cermak Station, Chicago

controls of flows and distant pumps to maintain perdetermined levels or rates, the proportioning of chemical dosages to main flows and other functions, are examples of modern metering requirements. The design and finish of the instruments themselves have been "modernized" to harmonize with the present architectural attractiveness of plant interiors. Effective illumination has been likewise provided for single- and double-faced master indicating gauges, frequently of large diameter.

A flow and ratio gauge for each unit in a modern activiated sludge plant is illustrated, Fig. 17. There are five dials, the three largest showing (left to right) rates of air flow, sewage flow and return sludge flow to an aeration tank. The two smaller dials show (left) the ratio of air to sewage—in cu. ft. per gal., and (right) the ratio of return sludge to sewage—in per cent of sewage flow. In addition, there is an automatic control knob for pre-setting the latter ratio for any desired value. A pair of these five-dial gauges are mounted on one control table similar to those used in water filter plants.

Installation Requirements

To insure the proper application of metering equipment, specific data should always be obtained from the meter manufacturer for a particular installation. However, in general, certain standard requirements are noteworthy.

The Venturi tube should preferably be preceded by a straight length of pipe having the same diameter as the tube; this length being at least six times the tube diameter up to 24 in. and at least 12 ft. for larger sizes. Where space is limited, or there is the probability of turbulent or spiral flow ahead of the tube, straightening vanes may be required. Any kind of fitting may be placed at the outlet end of the tube. Since the centrifugal pump is almost universally used in water works and sewerage systems, pulsations in flow are rarely encountered. However, such condition may occasionally be presented and must receive special consideration. It is essential in making pressure pipe connections that they be run on a continuous grade, avoiding summits or depressions where air or silt may collect.

The Parshall flume must be set at the proper elevation with respect to the channel, preferably so that it can operate at all times under "free flow" conditions, with a limit of 95% submergence. It should be located in a reasonably straight section of channel, where the distribution of flow is fairly uniform. The flume, however, will operate satisfactorily under rather poor approach conditions. The dimensions and proportions of the flume must adhere to the established standards.

In installing the Kennison nozzle, care must be taken to provide proper approach conditions. This device should be preceded by a section of pipe at least eight diameters in length, and the water or sewage must flow smoothly from the nozzle under free discharge. Any conditions of installation which might cause a "shooting velocity" at times, should be corrected by the use of proper fittings upstream.

Orifice plates are more sensitive to approach conditions than Venturi tubes, and require a straight length of smooth pipe both upstream and downstream from the plate. For the upstream, the length required may vary from five to thirty diameters, while for the downstream length—up to eight diameters, depending upon the piping layout and the diameter ratio. Straightening vanes may be required to eliminate swirls, cross currents and eddies; their use may make it possible to shorten the necessary lengths of pipe as just mentioned.

Conclusion

Certain fundamentals of main line metering and some of the modern developments in metering equipment have been briefly discussed. Emphasis is placed upon the importance of regarding each meter installation as an engineering problem, which requires the consideration and advice of experienced manufacturers. Low cost equipment may properly serve for relatively unimportant work, but is entirely unsuitable for checking the daily performance of main units and for controlling the efficiency of treatment processes. In general, the highest grade of equipment as offered by prominent manufacturers cost only a small fraction of the total construction contract on important projects. Obiviously, the best is the wisest selection.

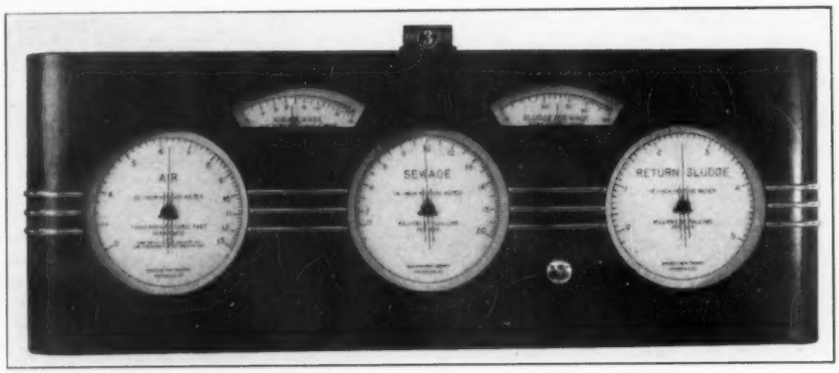


Fig. 17—Special Flow and Ratio Gauge for Modern Activated Sludge Plant, Baltimore, Md.

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PRODUCTS

VENTURI

Venturi Meters for Water, Sewage, Sludge, and Air; Flo-Watch Meters for relatively less important lines; Venturi Rate of Flow Controllers; Loss of Head and Rate of Flow Gauges; Reservoir and Tank Elevation Gauges; Sewage, Sludge, and Air Flow and Ratio Gauges. Chronoflo Meters for Distant Metering. Summation of Meter Totals, Continuous Sludge Weighing Chemical Feeding, Suction Well Level and Pump Control. % Proportioneers % Chemical Feeders for Water and Sewage Treating.

VENTURI METERS—for Water Works and Sewage Plants

Fig. 1. The Venturi Tube

The Venturi Meter is recognized as the standard means of measuring the flow of water in large mains. It consists of the Venturi Tube (illustrated), installed as a section of the main, and the Register-Indicator-Recorder connected to the Tube by two small pressure pipes. For the measurement of liquids containing large amounts of solids, such as sewage or sludge, the *Air Relay Transmitter* is used to prevent the liquid measured from coming into contact with the Instrument.

Fig. 2. Type M Register-Indicator-Recorder (Model D-1)

Several different types of indicating and recording instruments are available for use with the Venturi Tube. The *Barometric Type Mercury Manometer,* with a flow rate scale graduated directly in flow units indicates rate of flow. The *Flo-Watch,* Fig. 3, for use on main lines in small plants and secondary lines in large plants, records, indicates, and totalizes the flow. The most popular instrument is the *Type M Register-Indicator-Recorder, Fig.* 2.

This Register has the advantage of unusual ruggedness and extreme accuracy. The Type M furnishes three distinct kinds of information; an indication of the momentary flow through the Venturi Tube; a permanent record of this rate upon a large circular chart; the total quantity on a circular counter dial. Each Type M is graduated for the particular Venturi Tube with which it is to be used.

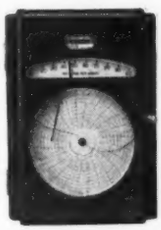


Fig. 3. Flo-Watch Register-Indicator-Recorder

VENTURI RATE OF FLOW CONTROLLER

Fig. 4. Type E Direct-Acting Controller

Effluent controllers automatically maintain constant rate of flow through the filter bed. Several types are available. Features of the Type E Direct Acting Controller (Fig. 4) include: precise control, low loss of head, rigid balanced valve, compact, yet flexible design, powerful "floating piston" actuation, and exclusive molded, tapered piston seal. Venturi Controllers have been standard equipment for many years.

BUILDERS WATER WORKS GAUGES

Loss of Head (through filter) and Rate of Flow (Filter Effluent) Gauges are usually mounted on each filter operating table. Indicating and Recording Water Level Gauges are also furnished.

BUILDERS SAND EXPANSION GAUGE

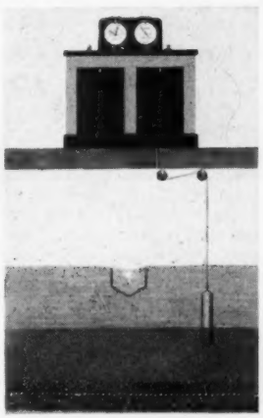


Fig. 5. Installation of Builders Sand Expansion Gauge

Shows % Sand Expansion in Filter Bed . . . High-Torque principle assures accuracy . . . Displacer combines power and stability . . . Adjustable for individual filters.

Builders Sand Expansion Gauge enables the operator to control both the *extent* and the *rate* of sand expansion in the filter bed. It operates independently of changes in wash water flow, pressure or temperature. Indicators and Recorders can be furnished in standard attractive designs for table or floor stand mounting. Large Indicators, 24" and 30" diameter, with white gas-tube illumination, are available for wall or ceiling mounting, using Chronoflo transmission between filter and Gauge.

CHRONOFLO METERS AND THEIR USES

Distant Flow Metering

Fig. 6. Chronoflo Recorder

Chronoflo Meters have found a broad application in bringing to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving and Recording Instruments. (Fig. 6).

Reservoir and Tank Elevation Gauges

in the pumping station and the water works office downtown, continuously indicate and record level in outlying reservoirs, tanks, or standpipes; eliminate the necessity of taking such measurements manually; and promote efficient pumping.

Distant Transmission and Summation

The Chronoflo Meter is peculiarly suitable for adding the totals of various individual meters installed in widely separated locations.

Continuous Sludge Weighing

In many sewage plants one measure of efficiency of operation is the weight of filter cake carried from rotary filters to final disposal. A recent development is the attachment of a special Chronoflo Weight Transmitter to a Toledo Automatic Scale, which integrates on a counter the total pounds and records on a continuous chart the rate in pounds per hour.

ENGINEERING SERVICE

Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed bulletins, illustrating and describing devices mentioned briefly in these pages, are available upon request.

WATER HAMMER

Its Study and Correction

By HENRY RYON
Senior Sanitary Engineer
N. Y. State Dept. of Public Works
Albany, N. Y.

IN ORDER to provide water for Clinton Prison at Dannemora, N. Y., it was found necessary to use Chazy Lake as a source of supply and to lift the water over Dannemora mountain to the prison reservoir. This required the installation of a pumping station and a force main about 4½ miles long with a rise of 530 feet. The pumping station and pipe line were put in operation late in 1932, and almost immediately trouble was experienced due to the failure of the lead joints in the pressure line. The cause of these failures was apparently the high pressures developed when the pumps were stopped, and studies were made to determine the best method of reducing these high pressures.

Installation

The pumping equipment consists of two electrically driven four-stage centrifugal pumps each having a capacity of 390 gallons per minute against a head of 619 feet. The pumps are set approximately at normal lake level. The suction line is of 10-inch cast iron pipe and is about 400 feet long. The discharge main is of 8-inch cast iron bell and spigot pipe, Class G to Class B, and is 23,720 feet long. The static head at the pumps is 530 feet, the equivalent of approximately 230 pounds per square inch. There is a standard swing check valve on the suction line and a similar check on the discharge line of each pump. A 6-inch spring loaded relief valve and an air chamber 8 inches by 96 inches in size were provided on the main discharge line near the pumps.

Line Pressure

In order to study the pressures in the discharge line a recording pressure gauge with a fast moving chart was connected to the line just beyond the relief valve. A typical pressure curve plotted by this gauge with one pump in operation and the relief valve and air chamber shut off is shown in Fig. 1.

The static pressure is 230 pounds per square inch. When one pump is started the pressure gradually rises to 310 pounds per square inch, the rise for each of the four steps of the starter showing distinctly, and then drops to the running pressure of 275 pounds per square inch. When the pump is stopped the pressure drops very quickly from 275 pounds per square inch to 90 pounds per square inch and then rises to 370 pounds per square inch. These subnormal and supernormal pressures continue at regular intervals, the variations above and below the static pressure becoming less and less as line friction gradually damps them out. The time of one complete cycle is 23.1 seconds, and since the water-hammer wave must travel four times the length of the pipe in one cycle, its velocity is at By comparison, the maximum velocity of flow in the pipe, with one pump in operathe high speed of 4,110 feet per second. tion, is only 2.49 feet per second.

It is, of course, the first super-normal pressure wave that causes most of the pressure wave cannot, however, be negdamage to the pipe line. The subnormal amount of air that can be retained in the lected for it very definitely limits the air chamber.

Water Hammer Waves

In order to explain the method evolved to control the water-hammer pressures, it is necessary to consider first the nature of a water-hammer wave. The magnitude and velocity of the wave depend upon the elasticity of the material composing the pipe wall, the velocity of the water in the pipe and the time in which that velocity or part of that velocity is extinguished. The yare independent of pressure in the pipe and flow velocity, except that part of the velocity that is extinguished. The water-hammer pressure or excess pressure is the variation above or below normal caused by the water-hammer wave. In this case (and in other cases where conditions are similar) the momentum ceases to deliver water almost instantly. The suction line being of the rotating parts of the pump and motor is so small in comparison with the load that when the switch is opened the pump short, no high pressure of any duration is developed in it that might force water through the pump. As a result the stopping of the pump has for all practical purposes the same effect as almost instantaneously closing a valve.

An Analysis

This effect can be examined best by considering the pipe line to be divided into a large number of very small sections of equal length.

When a valve at the inlet end of a pipe in which water is flowing is instantaneously closed, the velocity of the water in the section adjacent to the valve (in this case the pump), is immediately extinguished. This causes the water in this first section to expand, the pressure to fall and the pipe to contract. In other words, the kinetic energy of the moving water has been converted into potential energy. The water in the first section being at rest or static, the velocity of the water in the second section must necessarily cease. The water in the second section then expands, the pressure falls and the pipe contracts in the same manner as in the first section. This reduction in pressure in the second section in no way affects the pressure in the first section for the pressure in that section, excepting gravity and friction, is dependent entirely upon the destruction of the kinetic energy of the water in that section. And, the kinetic energy of the water

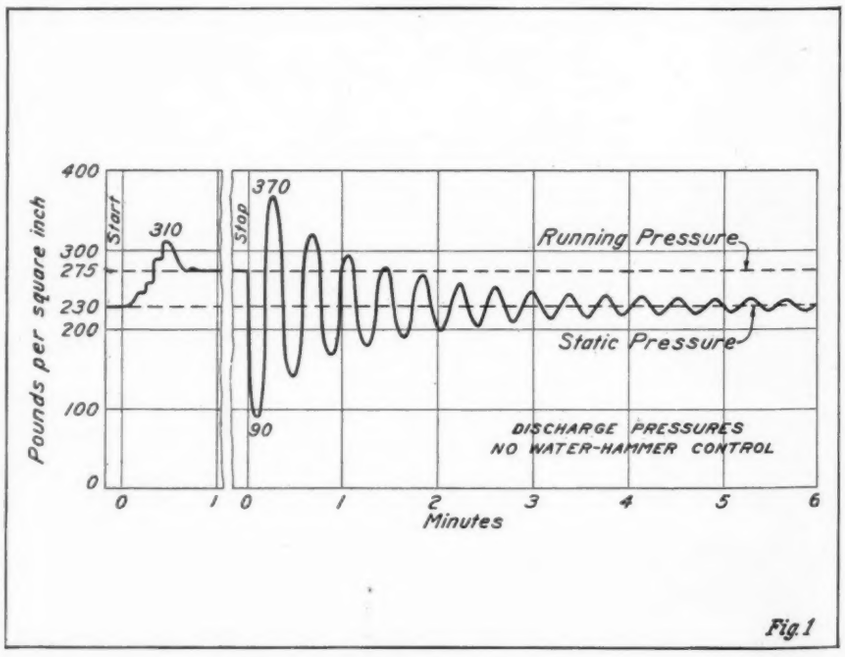


Fig. 1.—Typical Pressure Wave Graph
(One Pump Thrown Out; Relief Valve and Air Chamber Shut Off At the Time)

in the second section is exactly the same as that of the water in the first section and its destruction therefore produces exactly the same reduction of pressure. This process continues through the third, fourth and other sections of the pipe until all the water in the line has expanded, the entire pipe line contracted and the pressure throughout fallen by the same amount. The wave has traveled the length of the pipe once and the water is at rest.

This condition, however, is not stable. The water in the lower end of the pipe can-freeto contract. This it does immediately. not move, but the water inthe upper end is The water in the upper section contracts, the pressure rises and the pipe expands. As a result of this contraction of the water and the expansion of the pipe in the upper section, water flows into the pipe. Conditions in the upper section having thus changed, the second or adjacent section is free to move. The water in the second section then contracts, the pressure rises and the pipe expands. This draws more water into the pipe. In a like manner similar changes occur in the third, fourth and other sections until all the water in the line has again contracted, the entire pipe line expanded and the pressure throughout risen to the point (excepting friction at which it was before the valve was closed or the pump stopped. The wave has traveled the length of the pipe twice. The water is in motion and is flowing toward the pump with the same velocity, excepting for friction losses, at wlfich it was flowing away from the pump before the pump was stopped.

This flow cannot continue, for while the wave has been traveling twice the length of the pipe, ample time has elapsed (11.5 seconds in this case) for the check valve at the pump to close tightly. The flow is therefore directed toward a closed valve and the velocity in the first section adjacent tothe check valve is instantly extinguished. The water in this section is compressed, the pressure rises and the pipe expands. The water in the first section being at rest, the water in the second section must necessarily come to rest with the same changes in condition as occurred in the first section. In a like manner, the water in the third, fourth and other sections come to rest successively until all the water in the pipe line is at rest and compressed, the pressure above normal and the pipe expanded for its entire length. The wave has traveled three times the length of the pipe and the water is once more at rest.

Again, however, the conditions are unstable. The water in the lower end of the pipe cannot move but that in the upper end is free to expand. This it does immediately. The water in the first section expands, the pressure falls and the pipe contracts causing water to flow out of the upper end. Conditions having changed in the upper or first section, the second section is free to move. The water in the second section then expands, the pressure falls and the pipe contracts causing a further flow of water out of the upper end of the pipe. Similar changes occur in the third, fourth and other sections of the pipe until all the water in the pipe has expanded, the entire pipe line contracted and the pressure (except for friction losses) fallen to the normal running pressure. The wave has traveled the length of the pipe four times. The water is moving away from the pump with the same velocity, excepting friction losses, that it was before the pump was stopped. In other words, one cycle has been completed, and conditions are the same as when the pump was running.

The cycle repeats itself until the friction gradually damps out the wave.

A diagram of the effect of this wave near the pump is shown in Fig. 2. The complete cycle is from A to G. The slope of the line from B to C is due to the fall in friction pressure as the wave passes up the pipe and the water gradually comes to rest.

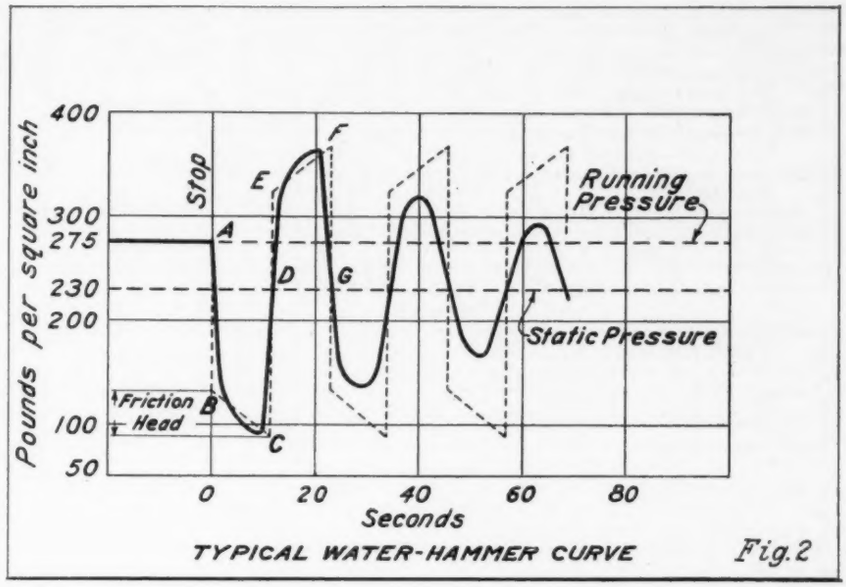


Fig. 2.—Graph of Wave Near the Pump (Explanation of Significance in Text)

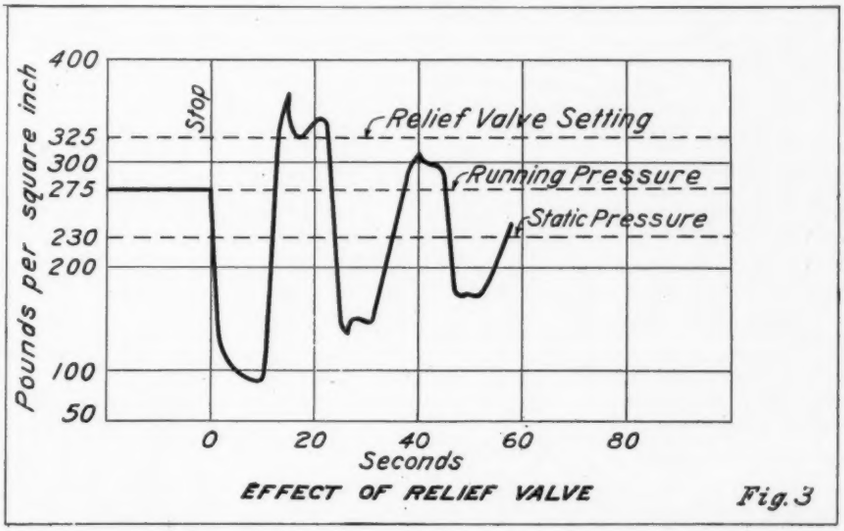


Fig. 3.—Graph Revealing Failure of Spring-Loaded Relief Valve to Relieve

The slope from E to F is due to the rise in friction pressure as the velocity away from the pipe is gradually regained.

A comparison of the velocities and pressure as observed and those computed by Joukovsky's formula (Jour. Am. Water Works Assoc., 1904, p. 341); (W. W. and S., April, 1938, p. 338) is interesting.

Joukovsky's formula for waterhammer, produced by instantaneous valve closure, is:

$$H = \frac{aV}{g}$$

$$a = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{K} + \frac{D}{Ee}\right)}}$$

H = Head due to water-hammer, ft.
a = Velocity of water-hammer water, f.p.s.
V = Velocity of water in pipe, f.p.s.
g = Acceleration of gravity.
w = Weight of one cubic foot of water.
K = Bulk modulus of elasticity of water, pounds per sq. in.
E = Modulus of elasticity of pipe material, pounds per sq. in.
D = Diameter of pipe, inches.
e = Thickness of pipe wall, inches.

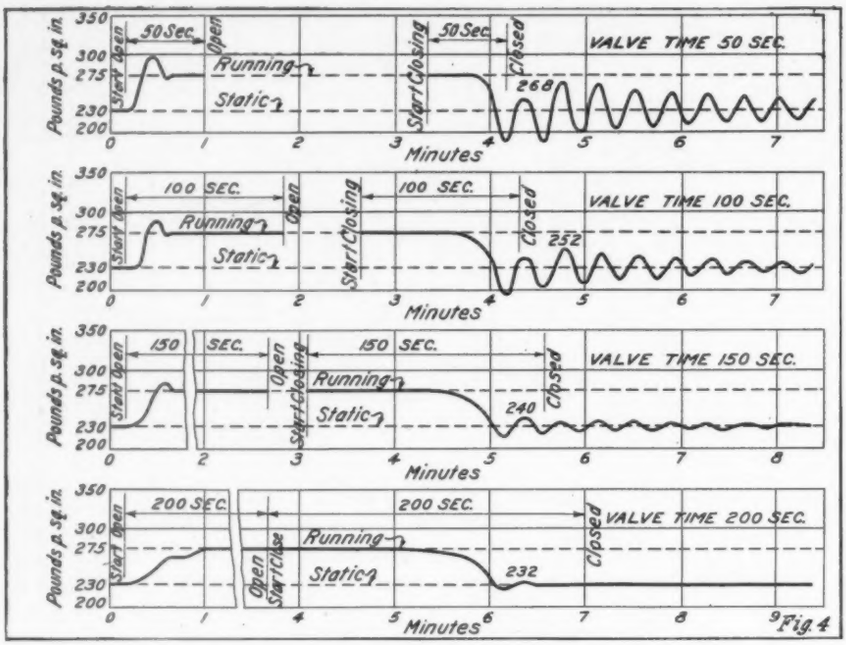


Fig. 4.—Graph Showing Results With a Cone Valve

The value of studying the effects of various closure times for surge suppression is effectively revealed in the four recorded graphs. A splendid testimonial as to the efficacy of properly controlled cone valves

The results are as follows:

Computed water-hammer head (negative)	326 ft.
Observed water-hammer head (negative)	322 ft.
Computed velocity of water-hammer valve	4220 f.p.s.
Observed velocity of water-hammer wave	4110 f.p.s.

If the pipe line had been shorter or the time of stopping longer so that the water-hammer wave set up by the first reduction in the discharge of the pump could have traveled to the end of the pipe and returned to the pump before the flow through the pump had stopped the returning supernormal wave would have interfered with the subnormal wave and the magnitude of the wave would have been reduced. So long as the returning wave does not reach the pump until its discharge is entirely stopped

$$t < \frac{aL}{2}$$

the result, for all practical purposes, is the same as that produced by an instantaneously closed valve. If it does return before the pump discharge has ceased, the interference of the waves must be considered. Except for this interference, the *water-hammer pressure is independent of the length of the pipe.* In the suction line which is only 400 feet long, the first wave returns in 0.2 of a second and interferes with the following waves, preventing, as stated before, the development of a pressure in the suction that might force water through the pump.

Relief Valves

When the Chazy Lake pumping station was built, a 4-inch spring loaded relief valve was installed on the 8-inch discharge line for the purpose of preventing any undue rise in pressure. This relief valve failed to produce the desired result. The effect of the relief valve on the water-hammer pressures shown in Fig. 3. The inertia of the moving parts in the valve apparently prevents it from opening rapidly enough to relieve the pressure and the head rises almost to the same value that it does without the valve in operation. When it finally does release the water the pressure falls to that for which the valve is set. The valve then closes and stops the flow of water through it. The stopping of this flow sets up another water-hammer wave and the pressure again rises.

In order to satisfactorily prevent high pressures by means of a relief valve, the valve must open *before* the first returning wave reaches the pump. That is, before the pressure reaches the point D in Fig. 2. At this time the water in the line is flowing toward the pump and the pressure is the normal static pressure. If the valve is open at this time the water will flow out of the valve with no material rise in pressure. The valve must close slowly or the stopping of the flow through the valve will set up another water-hammer wave with consequent high pressures. It is generally necessary to provide an auxiliary source of power if this method of preventing high pressures is used because the pressure in the lin eis subnormal at the time the valve must start to open and usually insufficient to operate any type of valve.

This arrangement is used effectively at the Dalecarlia Pumping Station, Washington, D. C. (Water Works and Sewerage, April, 1938, Page 353).* In this case the relief valve is of the hydraulically operated rotary plug type and the power for opening it is obtained from an independent water main near the station.

Air Chambers

The 8-inch by 96-inch air chamber provided on the discharge line from the pumps was found on test to be of absolutely no value in reducing the water-hammer pressures, and computations by the graphic method of Prof. Angus indicated that no reduction could be expected. An air chamber on the discharge line of a pump acts by supplying water to the line in gradually decreasing quantities after the pump has stopped, causing a gradual reduction in the velocity in the line instead of a sudden closed valve.

To prevent high pressures in a pipe line by closing a valve slowly instead of rapidly requires that the time of closing be considerable, and if an air chamber is to be effective it must supply water to the line for a considerable time. Not only must the air chamber be large enough to contain sufficient water to the air chamber be large enough to contain sufficient water to maintain this supply over the necessary period, but there must be sufficient air above the water to maintain the proper pressure on the water as the air expands. Air chambers, if they are to

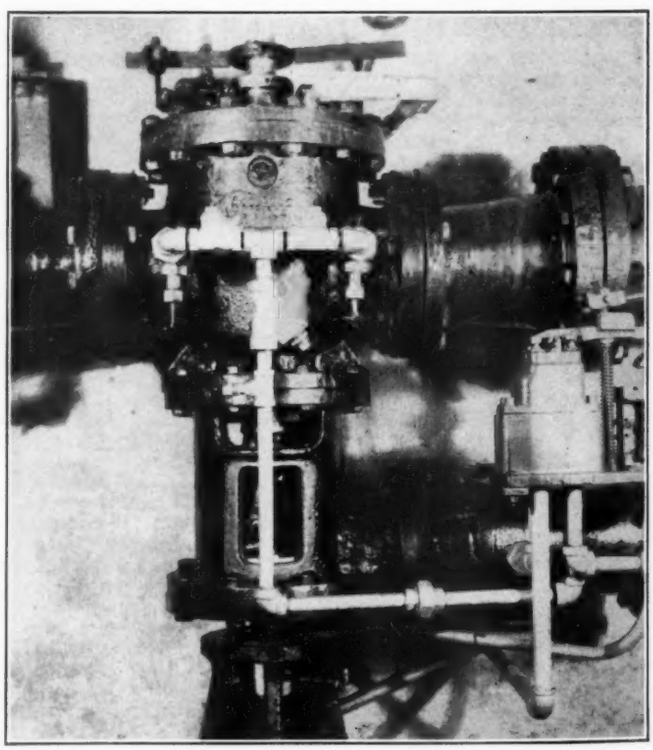


Fig. 4.—The Cone Valve

Which, with proper setting for closing time has solved the water-hammer problem

produce any measurable effect, must be far larger than those usually provided and often so large as to be impractical. Tests are now being conducted at the pumping station of another institution to determine the effects of air chambers of different sizes, but the results must await later publication.

Cone Valve in Discharge Solves the Problem

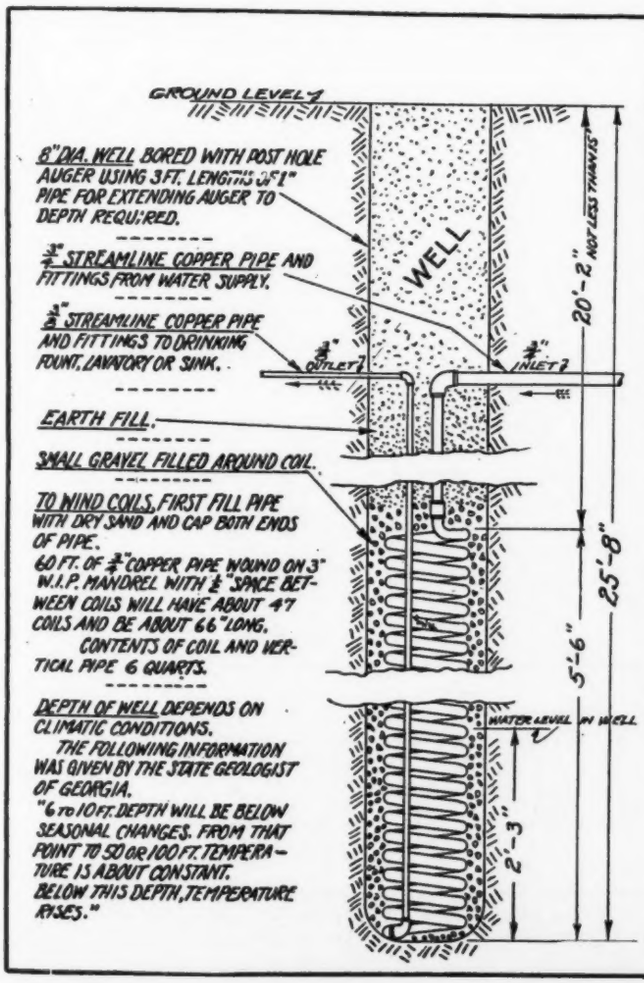
The method now used at the Chazy Lake pumping station to eliminate the high water-hammer pressures is to reduce slowly the velocity in the discharge line before the pump being used is stopped—this instead of allowing velocity to be suddenly extinguished by the stopping of the pump. This is accomplished by a 6-inch hydraulically operated cone valve located in the main 8-inch discharge line near the pumps (see picture). The cone valve is in closed position when the pump is started. Since a centrifugal pump requires the smallest amount of power when operating against a closed valve, the motor thus starts under minimum load. As soon as the pump reaches its normal speed the cone valve slowly opens, the time of opening being controlled by the setting of a needle valve on the water feed-line to the hydraulic cylinder operating the cone valve. When it is desired to stop the pump the cone valve is first closed slowly, gradually reducing the velocity in the discharge main. After the valve is entirely closed the pump is stopped in the ordinary manner. Electrical interlocks are provided so that the attendant cannot change the order of the operations.

Results

The results of this method of operation, for different timings of the valve, are shown in Fig. 4. This valve rises from its seat before turning and reseats itself after completing its rotary motion. The time given for opening and closing is the time taken for the valve to rotate through 90 degrees, and does not include the time taken for unseating and seating. There is some leakage past the plug when it is raised from its seat, and the stoppage of this leakage by the seating of the valve in some cases causes a slight secondary wave, as is noticeable in some of the curves. The destruction of the velocity in the pipe line is, of course, not proportional to the amount of rotation of the valve as is evident from the fact that the first 2/3 of the revolution produces no measurable effect on the pressure. The effective closing time is therefore only a fraction of the actual closing time. Setting the valve to close in 50 seconds keeps the water-hammer pressure below the running pressure. Further, increasing the time of closing reduces the water-hammer pressure until with a closing time of 200 seconds the excess pressure caused by water-hammer is scarcely noticeable.

At this pumping station only one pump should be operated at a time if economical results are to be obtained. Two pumps can, however, be operated at once with a consequent decrease in the delivery per pump and a decrease in efficiency. The water-hammer pressure produced by closing the cone valve with two pumps in operation is practically the same as that produced by closing the valve with one pump in operation, the time of closing being the same. The reason for this is that while the actual closing time is the same, the effective closing time, as indicated by the curves, is about twice as long with two pumps in operation.

This method of reducing water-hammer pressures does not protect the discharge line from water-hammer pressures due to power failure. Such protection can be afforded only by a properly timed relief valve operated by a separate source of power or by the use of an air chamber, both of which methods have been station, neither of these methods seemed practical because of the previously mentioned. In the case of the Chazy Lake pumping difficulty of securing a separate source of hydraulic or other power; and, the very large size of the air chamber required to produce even a small reduction in the excess pressure. At this station the water-hammer pressures do not rupture the pipe but do strain the lead joints, and the high pressures can be repeated several times before leaks occur. For these reasons, it was decided to protect the pipe line against the high pressures produced by the daily starting and stopping of the pumps, and to risk occasional high pressures due to power failures which may occur at very infrequent intervals.


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH 1" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET
INLET
20'-2" NOT LESS THAN 15
25'-8"
5'-6"
WATER LEVEL IN WELL
2'-3"

COIL WELL AT PIPE YARD
ATLANTA WATER WORKS

DEPTH OF WELL..... 25'-8"
DEPTH OF WATER IN WELL..... 1'-0"

		Air Temperature At Surface	Tap Water Temperature	Coil Water Temperature	Air Temperature At 15 Ft. Depth	Water Temp. At Bottom of Well	
7-19-34	9:00 AM	87°F.					
7-19-34	11:00 AM	89°F.			66°F.		
7-19-34	1:00 PM	77°F. RAINING				65°F.	
7-23-34	11:00 AM	91°F.	87°F.	66°F.			
7-24-34	2:00 PM	93°F.	87°F.	66°F.			
8-23-34	1:00 PM	88.5°F.	83.5°F.	66.0°F.			
4" DIA. DRIVEN WELL AT DWELLING ON TRACBERT ROAD DEPTH OF WELL..... 29'-0" DEPTH, WATER IN WELL..... 1'-0"							
10-2-34	10:30 AM.	82°F.			65°F.	64°F.	

THE FOREGOING DATA SECURED BY L.W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYCOS THERMOMETER No. 9T6872.

NEWS ITEM—
"THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120°F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5 DEGREES FOR EVERY 1,000 FT. OF DEPTH."

CONCLUSION

DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PIPING INCLUDING COIL BEING OF COPPER, THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.

UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS
AT HEMPHILL PUMPING STA. PIPE YARD

DESIGNED BY W.M. RAPP, SUPT.
DEPT. OF CONST. & DIST.
ATLANTA WATER WORKS
ATLANTA..... GEORGIA

SCALE:- 1½" = 1'-0" OCT. 5, 1934

S-75

WATER SUPPLY IN FIRE PROTECTION

Some Pointers and Considerations, Based Upon Experience and Observations

By RICHARD BENNETT
Hydraulic Engineer
City Engineer's Office, Phoenix, Arizona

FIRE protection has always been one of the primary responsibilities of municipal government. From the earliest ages the cities have equipped and maintained fire departments. Fire laws and building regulations for fire protection have been known since the earliest times. In fact, our word "curfew" comes from the Middle Ages when in France there was a strict law requiring all fires in residences to be put out at sundown.

The economics of fire protection revolve wholly around the insurance rates. Fire insurance is as old as fire protection, and today we find practically every property owner, whether in the small town or the big city, completely protected by it. The insurance premiums he pays are just as important to him as his city taxes, and in many places these premiums exceed his city taxes.

Fire Protection Based on Sound Economics

This means that there can be definite economic planning of fire protection. Additional fire protection naturally must raise the tax rate but if the insurance rates can be reduced in a greater amount than the increase in taxes, then the property owner has received a net benefit. If the cost of increased fire protection, as reflected in taxes, is greater than the saving in insurance rates, then it is obviously uneconomic.

We have a striking example of the working of this law of economics here in Phoenix when we submitted to our voters approximately a million dollars' worth of bonds for improving the water supply and fire alarm systems. It was proved that the reduction of insurance rates to be secured would more than offset the additional taxes caused by the bond redemption; therefore, it was economic to proceed with this work, and the voters gave their approval of the bonds.

Regardless of scientific advances, as yet nothing has been discovered which will put out fires so well as water. This means that if we are to put out fires and prevent conflagrations, we must have water available and plenty of it. The problem of water supply for fire protection is entirely different from that for domestic consumption. Fire protection is graded from two points of consideration: 1st, adequacy to meet requirements; 2nd, reliability to maintain adequacy. While both these requirements are desirable for domestic supply, purity is essential with softness and freedom from taste, odor and color being of prime importance. Domestic consumers will permit of low pressures and certain interruptions to continuity of supply, but such cannot be tolerated for fire protection.

For fire protection there must be an adequate supply of water to put out the worst anticipated fire, and this amount of flow must be available every minute of every day of the year.

This means that water supply systems for fire protection must be especially designed and for small towns will necessarily cost far more than if only domestic consumers were to be served.

Water Supply Counts for 34% in Insurance Ratings

The National Board of Fire Underwriters assigns 34% of the entire fire protection to the water supply. Another 30% depends on the fire department itself, and the balance is distributed among such items as climate, prevailing winds, fire alarm system, building ordinances, etc. Thus it is seen that fire insurance rates depend to a great extent upon the adequacy and reliability of the water supply.

With more than one-third fire protection requirements depending upon the water supply, it is imperative that municipal officials who are responsible for providing the most economic fire protection for their particular city have a working idea of the requirements which must be met to provide the necessary water for fire-fighting purposes.

To secure reliability the water must be available at all times. This may require a dual source of supply or may be met in many cases by providing an adequate amount of storage, utilizing two or more supply mains to the distribution system.

The factor of available quantity is usually the most difficult to meet. In practically all cities, including Phoenix, the original water supply system provided capacity for domestic use only and has been gradually converted into a fire protection system. In

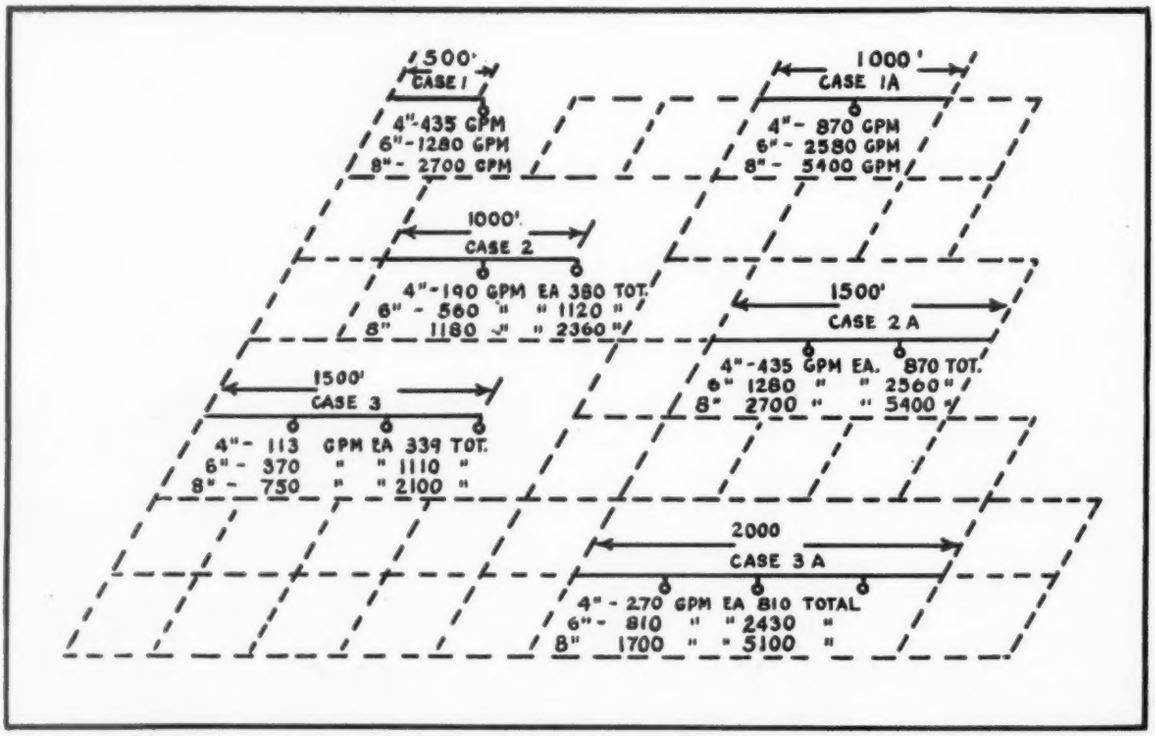


Fig. 1. Typical Gridiron Layout Showing Examples of Flow Available in Dead End and Connected Mains, Assuming a Uniform Pressure of 60 lbs. in Gridiron and 20 lbs. Minimum at Hydrants

general the gridiron mains and supply lines which were more than ample for domestic supply are totally inadequate for fire protection.

From the experience of many tests the Fire Underwriters have determined the amounts of water which must be available to cope with the fires which may be expected in cities of various sizes, a table of which is given in the Standard Grading Schedule issued by the Fire Underwriters.

Methods of Correcting Deficiencies Frequently Simple

Too often it is found that a city will receive many deficiency points which influence its fire rates due to the inadequacy of the distribution system to carry the required fire flows. For small towns the standard minimum fire flow is 1,000 gallons per minute in addition to the maximum daily domestic consumption. When small mains are installed and especially if any unconnected ends, commonly called dead ends, exist, then the capacity of the system is seriously impaired.

In order to show the serious effect of small dead end mains in the system, illustrative examples are given in Fig. 1.

The Fire Underwriters grade hydrants on the basis of being able to deliver not less than 600 gallons per minute.

In Fig. 1 the dashed lines represent a typical gridiron layout which has ample capacity to meet all consumption demands and it is assumed that the pressure in these mains, at any rate of flow in the examples given, is 60 lbs. per sq. in. and it is further assumed that all blocks are 500 ft. long. The capacity of mains is graded on the ability to maintain 20 lbs. per sq. in. pressure in the system at maximum flows.

The dead end main shown in Case 1 is 500 ft. long and for ordinary friction values has the following capacity:

Size of Main	Capacity G.P.M.	Fire Underwriters Required Capacity
4″	435	600
6″	1280	600
8″	2700	600

This shows that a 4-inch main will not deliver the required amount of water, and furthermore if a single valve is closed then all capacity of this dead end main is lost.

Case 1A shows the main extended such that it is fed from two ends. The capacity of this main is as follows:

Size of Main	Capacity G.P.M.	Fire Underwriters Required Capacity
4″	870	600
6″	2560	600
8″	5400	600

This indicates that the main has the required capacity but if a single valve were to be closed at either end then the 4-inch main would have insufficient capacity as shown in Case 1.

Cases 2 and 3 show dead end mains respectively 1,000 and 1,500 ft. long while Cases 2A and 3A show these mains extended and connected to be fed from both ends. The capacity in gallons per minute of these mains is as follows:

Case Number	Size of Main, Ins.	Capacity of Each Hydrant	Capacity of All Hydrants	Fire Underwriters Required Capacity
2	4	190	380	1,200
2	6	560	1,120	1,250
2	8	1,180	2,360	1,200
2A	4	435	870	1,200
2A	6	1,280	2,560	1,200
2A	8	2,700	5,400	1,200
3	4	113	339	1,800
3	6	370	1,110	1,800
3	8	700	2,100	1,800
3A	4	270	810	1,800
3A	6	810	2,430	1,800
3A	8	1,700	5,100	1,800

In grading a system all 4-inch mains and 6-inch dead end mains receive a deficiency rating, and these illustrative examples show the justification for such action, as they have inadequate capacity and reliability to meet demands which may be made.

The fire underwriters recommend that 6-inch mains be used only where they complete a good gridiron, and in no case in blocks 600 ft. or more in length; that not more than one hydrant be placed on a 6-inch main between intersecting lines, and not more than two hydrants on an 8-inch main between intersecting lines.

Some Case Records and Corrections

In many places it is possible to increase the reliability of the water works by simple changes in operating practice, as is illustrated in the actual case shown in Fig. 2.

This Arizona town has a gravity domestic supply with a stand by pumping system for fire service and was operated in case of fire by closing a manual valve in the tank line at Point "A" after the pumps were started. Due to weaknesses in the system, only one pump was operated, and in a throttled condition to control the pressure.

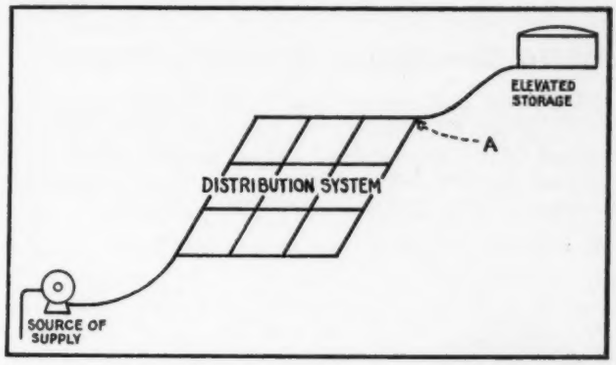


Fig. 2. A Good System (But subject to either right or wrong operation in fire service)

Differential tests on this system showed the city authorities the following startling condition:

	Static Pressure in System	Fire Flow Available Gal. per Min.
With tank only	43	628
With pump as for fire	68	475

In this case 32 per cent more water was available for fighting fires by depending on the tank rather than the fire pumps for supply. Under either method of operation this system was inadequate to meet the standard minimum of 1,000 gal. per min.

A second Arizona town has a pump capacity and storage capable of supplying about 5½ million gallons per day but is limited to and receives credit for fire protection for about 3½ million gallons per day because of small mains in the distribution system.

In order to receive the greatest benefit in fire insurance rates the fire protection facilities must be consistent as the protection features are graded on the basis of the weakest link or limiting factors. A town may have a strong pumping system and adequate mains but will receive a heavy penalty under reliability if the source of power for the pumps is dependent on a long single transmission line subject to lightning damage, and alos if the supply main from pumps to system is a long single main where a single break would leave the town without water. A good water works with no organized fire department will not receive any credit, and in turn a strong fire department and weak water supply receives a penalty for divergence.

A third Arizona town purchased a 500 g.p.m. fire engine pumper. The distribution system had a single 4-inch main in the main street. Tests on this main showed a fire flow available of only 90 g.p.m. No fire insurance reduction was received for the purchase of the fire engine as the system was inadequate to meet the demands of such equipment.

A fourth Arizona town purchased a 750 g.p.m. pumper. This town has a direct pumping system and on receipt of fire alarms raised pressure to such an exetnt that there was available in the principal business district about 2,000 g.p.m. at 50 pounds residual pressure. This town, due to existing conditions, was receiving credit for two-thirds of this flow for fire streams without pumper capacity or about 1,350 g.p.m.; therefore, the purchase of the pumper did not secure extra credit for fire protection.

The various units of the water works should be balanced in order to receive the most fire protection. A fifth Arizona town had a strong pumping capacity in four pumps which was materially limited by the inadequate supply main to the town. With this small main, only one pump could be operated at one time. With a larger and more adequate supply main, several pumps could have been operated simultaneously in case of a big fire, and credit would be received for the other pumps for fire protection.

These few cases have been cited to show the advisability of checking with the fire underwriters as to the wisdom of all expenditures *before they are made,* in order to receive most credit for changes in the system of fire protection. The fire underwriters will not act as engineers to design your system, but I have always found them quite willing to pass upon any proposed plans, giving their ideas as to whether this, or something else, seemed the most practical expenditure which the town could make to improve its fire protection per dollar of investment.

R. D. COLE MANUFACTURING CO.

Est. 1854

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NEWNAN, GA.

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All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.

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Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service

1,000,000-Gallon "Cole-Shallow Depth" Tank

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Fabricated Steel Plate—The R. D. COLE MANUFACTURING CO. has a fully equipped plant for the fabrication of riveted or welded steel plate. In addition to the construction of its regular line of horizontal return tubular boilers, oil storage tanks, tubular heaters, etc., the company is prepared to construct special tanks and apparatus of any specified metal plate.

Alloys and Lining for Processing Apparatus—The facilities and experience of the company enable it to fabricate special apparatus of all kinds for the processing industry using alloy steel plates, stainless steel, nickel-clad steel, etc., or linings such as lead, tin, nickel or Monel.

ELEVATED STORAGE

The Value of Elevated Tanks on Water Supply Systems

By CHARLES BROSSMAN

Late Consulting Engineer, Indianapolis, Ind.*

In many cities the advantages of elevated water storage has been recognized, usually with considerable return on the investment.

On closed water systems without some form of storage facilities, where centrifugal pumps are in service, the pumps are usually installed large enough to take care of peak loads. It is quite evident that, with a pump available to take care of such peak loads, on the lighter loads (especially at night), the pump drops off greatly in efficiency, as does the motor. Such day in and day out waste of power mounts to an appreciable sum as time passes, until losses overbalance the costs of providing storage on the system —in instances many times over.

For instance: Assume a modern pump operating at full load efficiency of 70%, and motor at 90%. The unit will give a combined efficiency of 63%. This pump on the lighter loads, with a drop in efficiency of 50%, and the motor at 80%, gives a combined efficiency of only 40%, a difference between the two of 23 points.

It is readily realized that with such a condition recurring daily, the power consumption may be surprisingly increased for the year. Not alone such current waste, but if power is being purchased with a maximum demand charge on the motor size the rate will be increased due to this factor, for the reason that the pump motor must be large enough to take care of the peak load. On the other hand, an elevated tank will allow more uniform pumping, the pump and motor size can be reduced, thereby reducing the costly demand factor.

Another very evident disadvantage is that pressure is lost immediately whenever pump service is interrupted for any of several possible reasons. In case of fire such is disastrous. In any case, the public served is paying a penalty in insurance rates where pressure storage is not available on the system.

Furthermore, another advantage from elevated storage is that any pump on the line can be used at its maximum output, and with a correspondingly maximum efficiency. Pumps, therefore, can be purchased for use with elevated tank service over their maximum range of efficiency, with assurance that such efficiency can be realized in every day operation.

Another advantage is uniform pressure. With an elevated tank, automatic regulating control is available, whereby the tank variation in head may be kept within a few feet, thereby giving absolutely uniform pressures under all conditions of draft on the system. Particularly advantageous are elevated tanks in outlying districts, to reduce pumping costs and render better service pressures and flow. It is hardly necessary to indicate that more water will be used, in consequence, and a higher income enjoyed by the water utility.

In considering the values of elevated tanks for water storage it is apparent that there are a number of advantages.

Power Saving Case Records

The first advantage, that of saving in power cost, is the most appealing and in practically all cases a considerable saving in power will result. As a concrete example we may take the experience of a small plant in a town of 1,100 with which the writer is very familiar.

The Town of Albion, Indiana, had a water consumption of approximately 50,000 gallons per day. In this case an elevated tank was installed, the total cost of the tank being approximately $7,200.00. The power used before installing this tank, on the closed system, was approximately 1 KWH for 530 gallons; after the tank was installed, pumping was approximately 1 KWH for 1,050 gallons. This proved a spectacular attainment of cutting power consumption in half, but there are other Albions scattered over the country.

In this particular case, the tank will be paid for in less than 15 years by the saving in power bills alone. If the rate of consumption increases the time will be shorter, of course.

Here is a point of considerable interest in this case. Albion has its own generating plant, and the total cost of power is considered at 3c per KWH, including all costs. A careful check on all costs and power used still indicates the investment well justified. One reason is found in the fact that fire protection is now supplied with the small 200 G.P.M. pump and the large steam fire pump is no longer maintained as a ready to serve unit with fire in the boiler. Steam, however, can be had from the municipal power plant in case of necessity, and the pump is still available.

Another example is found in the City of Goshen, Indiana, where there has been installed a 500,000 gallon tank. The old plant was steam driven. About six years ago, the city installed a modern Diesel lighting plant, but only two of their deep well pumps were electrified at that time. The boilers had to be kept going at all times in the old steam plant, in order to have available suitable fire protection. In this case, a P.W.A. loan made it possible for Goshen to electrify its water works system. The city now has eight electric driven deep well pumps, and a new half million gallon tank. The loan by P.W.A. was negotiated on the basis of anticipated savings resulting from abandonment of the steam plant.

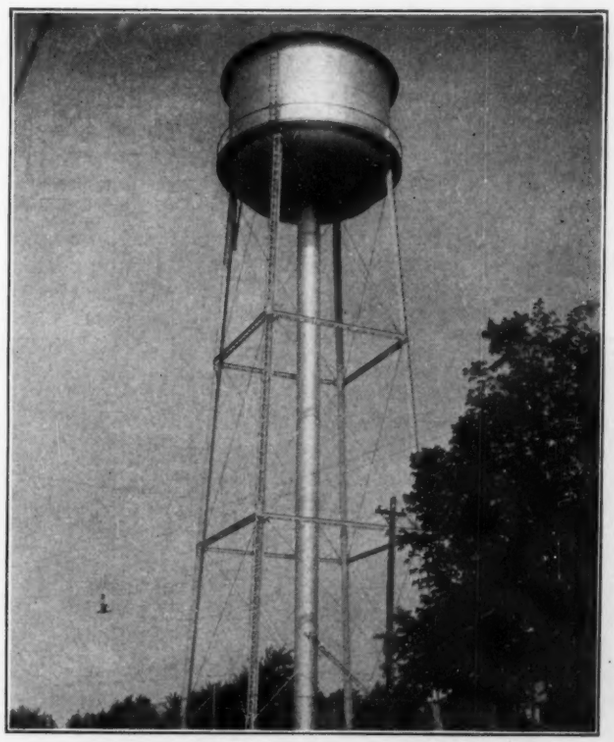
The cost of pumping for the old system on which boilers had to be kept up at all times, was given at approximately 8.3c per thousand gallons, which of course, was high, but the equipment was old, and used air lift pumps and double pumping, except for the two electric driven pumps.

It is estimated that the actual electrical pumping cost would be in the neighborhood of 1.2c per thousand gallons, and total cost at 2.2c per thousand. To take advantage of the potential saving (about 6c per thousand) an elevated tank had to be installed.

The old standpipe was not adequate for the demands, as the upper portion of this standpipe did not store very much water. The new elevated tank, of one-half million gallons, was installed some distance from the plant and on the opposite side of the city.

The entire pumping equipment is automatically controlled, there

(*Continued on Page* 48)



The 50,000 *Gal. Tank of Albion, Ind.*
Will pay for itself in less than fifteen years.

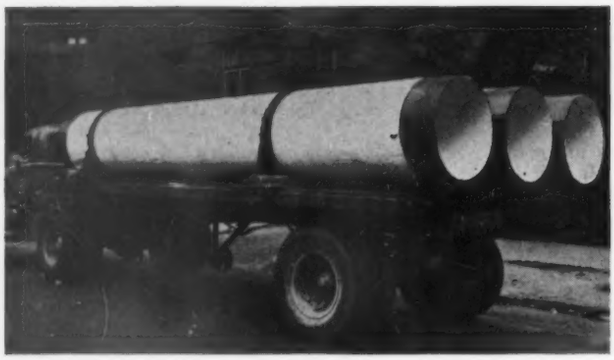
* Excerpts from a paper written by Mr. Brossman shortly before his death. It was presented before the Indiana Section of A.W.W.A.,

BINS, Storage
BREECHING, Steel
CHUTES, Steel
FILTRATION PLANTS
FLUMES, Iron and Steel
GAS HOLDERS
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel

CHICAGO BRIDGE

Chicago.....2198 McCormick Bldg. Dallas.....1679 Praetorian Bldg.
New York...3390-165 Broadway Bldg. Birmingham.....1586 North 50th St.
Cleveland...2262 Builders' Exchange Tulsa.....1646 Hunt Bldg.

Plants in CHICAGO, Ill.; BIRMINGHAM, ALA., and GREENVILLE, PA.



WELDED STEEL PIPE

Chicago Bridge & Iron Company offers complete facilities for fabricating steel pipe 30-in. in diameter or larger. Sections up to 60 ft. in length are tested, cleaned, grit-blasted, primed and coated on the inside and the outside all in one piece. The decrease in the number of field joints due to the use of long lengths results in an appreciable saving in installation costs.

The enamel lining, which is spun on the inside of the pipe centrifugally, gives steel pipe high carrying capacity. A similar coating on the outside protects the metal and assures long life.

The high tensile strength of large diameter steel pipe makes it particularly well adapted for high pressure line service and for large water mains in locations where they are subject to shock and vibration.

FACILITIES

We are equipped to design, fabricate and erect all types of steel plate work, riveted or welded. When requesting estimating figures on tanks, state capacity, height to bottom for elevated tanks, and describe location.

INFORMATION

We are always glad to supply municipal officials and water-works engineers with complete information or estimating figures on any or all of our products. Address our nearest office. There is no obligation on your part.

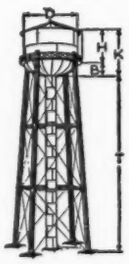
50,000-gal. Montrose, Minn.

200,000-gal., Hollywood, Fla.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

This type of tank is built in standard sizes as shown in the accompanying table. The tank diameter is relatively large and the depth shallow, reducing the variation in pressure between upper and lower water levels. Ellipsoidal-bottom tanks are available with two types of roofs; cone or ellipsoidal. Three typical cone roof tanks are illustrated below, and four tanks with ellipsoidal roofs and bottoms are shown above and to the right. This design provides a pleasing, modern appearance.

ELLIPSOIDAL-BOTTOM TANK SIZES

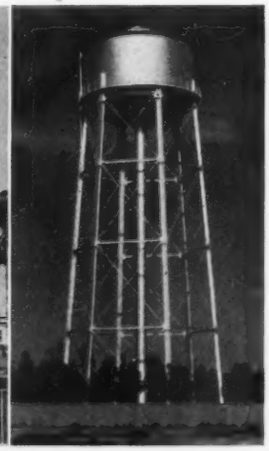


Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'9"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'9"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

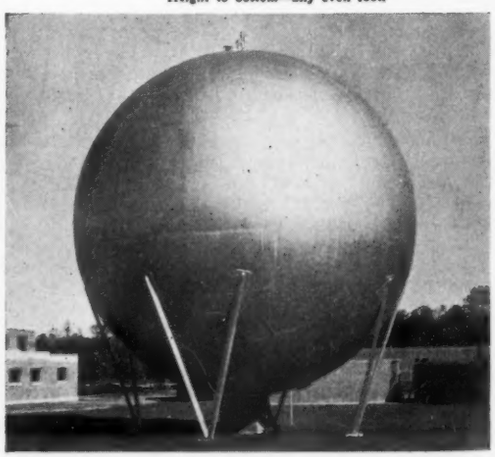
Height to bottom—any even foot.

50,000-gal., Mt. Palomar, Cal.

70,000-gal., Los Angeles, Cal.



250,000-gal., Brawley, Cal.



This 50-ft. diameter Hortonsphere is used to store sewage gas at 40 lbs. pressure at Sheboygan, Wis.

& IRON COMPANY

Houston.....5621 Clinton Drive
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Philadelphia....1644-1700 Walnut St.
Boston...1548 Consolidated Gas Bldg.
San Francisco.....1083 Rialto Bldg.
Los Angeles.....1455 Wm. Fox Bldg.

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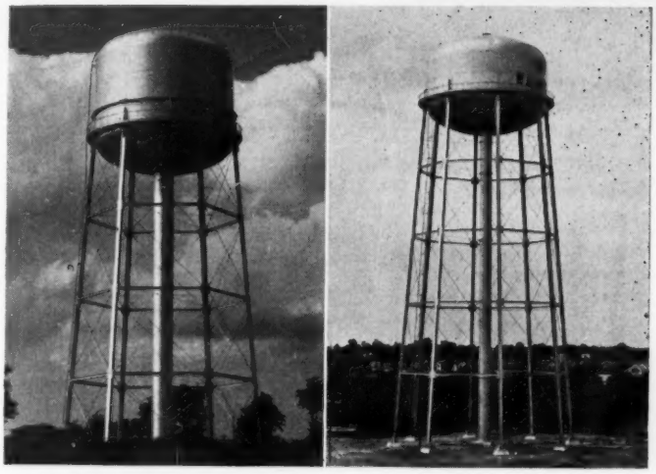
PRESSURE VESSELS, Welded
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES

STEEL PLATE WORK
TANKS, Elevated Steel
TANKS, Storage
TANKS, Surge
TANKS, Washwater

Three large capacity Horton radial-cone bottom elevated tanks are illustrated at the right. Capacities and locations are as follows (left to right): 500,000-gal., Holland, Mich.; 1,000,000-gal., Tucson, Ariz.; and a 1,500,000-gal. "Colonial" design unit installed at Hammond, Ind.



300,000-gal., Pleasant Hill, Md. *500,000-gal., Bristol, Penna.*

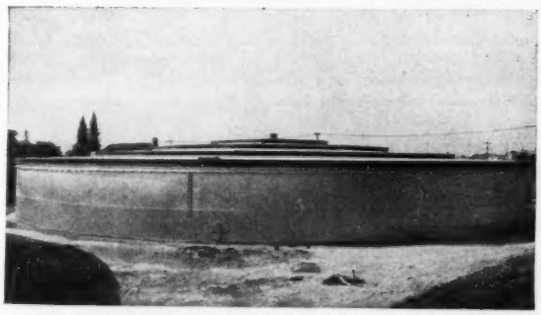
RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to permit the construction of large capacity tanks with a small range in head. (See installations shown above at Holland, Mich.; Tucson, Ariz.; and Hammond, Ind.) Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for the various capacities.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61′	25′
750,000	76′ 8″	25′
1,000,000	87′	25′
1,500,000	106′	25′
2,000,000	122′	25′

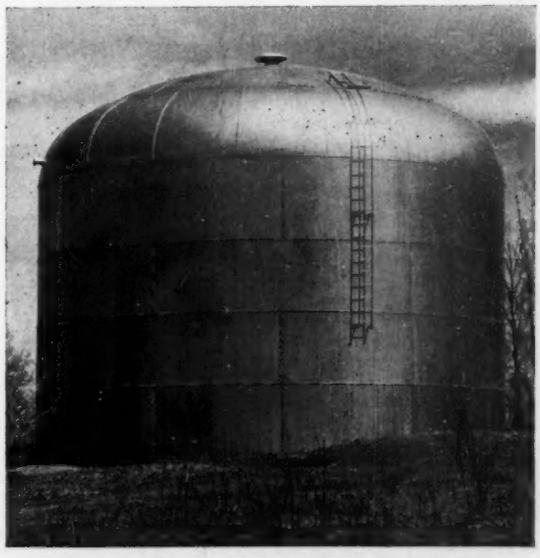
A new booklet is now available, showing numerous radial-cone bottom installations. Copies will be sent on request.



RESERVOIRS

Where natural elevations are available, flat-bottom steel reservoirs provide efficient gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.

Left: One of two 2,300,000-gal. all-welded steel water reservoirs installed at Alhambra, Calif.



300,000-gal., ellipsoidal-roof, flat-bottom water storage tank at Eden, New York.

100,000-gal. wash water tank at Michigan City, Ind.

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head, and pressure variation required for washing filters.

SEWAGE GAS HOLDERS

When gas from digesters at sewage disposal plants is utilized, excess quantities produced during peak periods can be stored advantageously under pressure in a Hortonsphere for use during off-peak periods. Hortonspheres are relatively small in size and pleasing in appearance. We also build conventional lift-type gas holders.

being two automatically controlled pumps at the tank site (about 1.5 miles from the main station), and six automatically controlled deep well pumps at the main station, each pump having a capacity of 500 G.P.M. Any pump can be manually started or stopped by push button control from the main plant.

Results at Goshen

Merle J. Miller, Superintendent and Manager of the Goshen plant, has made it possible for me to take the following from his report on the Goshen betterments.

"With a stand-pipe of the small capacity that we had previous to the erection of our new elevated tank, our water circuits were only fairly stable, but since the additional storage capacity has been added to our system, it has made a wonderful change in our water pressure charts as there is more cushion and no surge anywhere along the line. A number of charts taken at the elevated tank location have been absolutely perfect from the standpoint of surges or variation in pressure. We found before, especially with the steam pumping equipment, that we could detect each pulsation of the steam pump, as our standpipe capacity, at that time, was not enough to cushion the whole system properly. Comparing the old system as against the new system for uniform pressure, there is a vast difference. From the new system, if given any attention at all, we get a chart of uniform pressure, with as little variation as one pound.

"We also find a marked difference in the circulation of the water in districts where we had frequent complaints during the warm summer months against the warm stagnant water."

From the foregoing, it will be seen that in any plant that does not have an elevated tank, or if they have a standpipe of very small capacity, with very little water available in the upper section, the modern type of elevated tank, with all of the storage at the proper level, will almost invariably result in a financial saving, as well as give the other advantages which accrue to it.

Concerning Fire Protection Requirements

The relation of the elevated tank to fire protection is one of the important factors that should not be lost sight of. Modern elevated tanks, as compared to old standpipes, are much different for the available capacity for fire fighting facilities, as credit for water in a standpipe is only allowed for the top sections. Modern tanks, as now designed, keeps the water level to within a few feet variation, dependent more or less upon type of regulating control on the electric pumps.

Fire flows should not be confused with the total daily flow or capacity. For instance: if a town has a total available supply and storage based on a 24-hour period the fire flow will usually be based on a 5-hour flow for communities of 2,500 and less, which means that they will need 4.8 times the average consumption capacity as storage capacity for fire. For cities above 2,500 the multiplier will be 2.4 times for fire storage, as against consumer use storage. Such is based on a requirement of capacity for not less than a 10-hour period of continuous fire flow.

The fire flow requirements for average cities are given by the Underwriters, as follows:

Population	Required Flow (G.P.M.)
1,000	1,000*
2,000	1,500*
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000

* For 5 consecutive hours; all higher flows for 10 consecutive hours.

Therefore, in selecting the tank the fire flow for the period required, according to population, is the primary consideration. To this must be added the domestic consumption.

One of the Two 1,500,000 *Gal. Tanks of Indianapolis*
A leafy green and silver structure which constitutes a study in "neighborhood-treatment" of water towers.

This amount indicated is then balanced against the available low lift capacity of the pumps, such as wells or filters, also the ground storage capacity. The total low lift and ground storage capacity is then determined.

The second step is to figure the high lift pump capacity and the elevated storage capacity.

After these two quantities are known, they are compared to the required fire flow and domestic flow over the 5 or 10-hour period, as the case may be. This will then give the ideal condition in installed pumping capacity and tank size.

In case these conditions are not met, if there is a deficiency in pumping capacity or storage on either the low lift and ground storage or high lift and elevated storage, this deficiency will be taken into account in the making of rates.

It should be clearly kept in mind that the total 24 hours available capacity is not what is considered by the Underwriters. They base the capacity wholly on the fire flows listed for the period of hours noted.

Concerning Tower Heights

The matter of pressure from elevated tanks should not be lost sight of, as various pressures are required for certain types of buildings, according to the size town and construction therein.

One of the outstanding tank installations in this country, is that installed by the Indianapolis Water Company.

This large tank is located in the eastern section of Indianapolis, which is approximately 100 feet higher than their main pumping station. With this long line of pipe, and the ensuing friction losses, pressures were previously very low in this district. It was decided, after considerable study of ground as elevated storage, to erect an elevated tank with 1,500,000 gallons capacity to serve the approximately 64,000 people in this district. This tank has resulted in great improvement in pressure and supply, with an ensuing satisfaction to the water consumers.

This tank is the largest one in the state of Indiana on a public water supply, the tank being 72 feet to the bottom, and with this large capacity, having a range of only 25 feet between the upper and lower water levels. As the result of benefits noted the Water Company is undertaking a tank of like capacity in another section.*

In conclusion, I would state that there are many plants on which a study of water storage as well as pump efficiencies connected therewith; would result in a marked saving in the operation of such plants.

* Since the writing of this paper the second tank has been erected and placed in service. This installation, with the new Cathodic-protection system for safeguarding its interior against corrosion, is fully described in the November, 1939 issue of "WATER WORKS AND SEWERAGE."

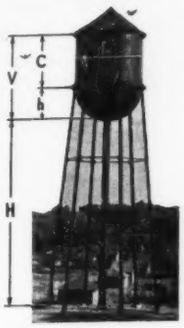
PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Sales Offices at: 3416 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE STREET, DES MOINES, IOWA
ROOM 918—270 BROADWAY, NEW YORK . . . 1222 FIRST NATIONAL BANK BLDG., CHICAGO, ILL.
1223 PRAETORIAN BLDG., DALLAS, TEX. . . . 625 RIALTO BLDG., SAN FRANCISCO, CALIF.

In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks

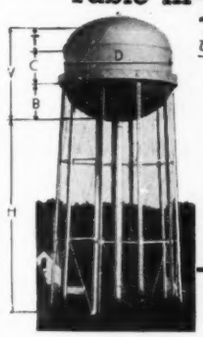


Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 6	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 6	141 6	153 4
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7
600,000	44	38 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	50	34 9	57 5												
1,000,000	50	52 0	73 9												

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks

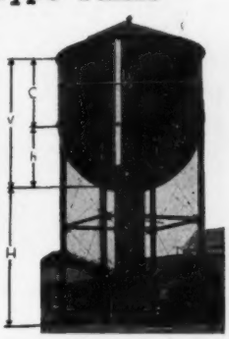
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 5
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90′ 3″	22 6	50 0												

Table III—Double Ellipsoidal Tanks



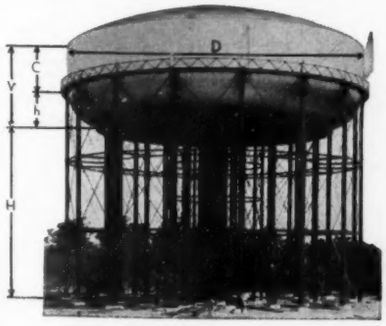
Capacity in U.S. Gallons	D	B	C	T	V	H
50,000	22′-0″	5′-10″	9′-4″	4′-4″	19′-6″	
75,000	26′-0″	7′-0″	9′-0″	5′-0″	21′-0″	
100,000	28′-0″	7′-0″	11′-1″	5′-7″	23′-8″	
150,000	34′-0″	10′-0″	8′-8″	6′-10″	25′-6″	
200,000	36′-0″	9′-0″	12′-11″	6′-9″	28′-8″	
250,000	40′-0″	10′-4″	11′-7″	7′-6″	29′-5″	Built
275,000	40′-0″	11′-11″	13′-9″	7′-6″	33′-2″	to
300,000	40′-0″	8′-7″	17′-11″	7′-6″	34′-0″	
350,000	44′-0″	14′-8″	13′-10″	8′-0″	36′-6″	Order
400,000	46′-0″	12′-2″	14′-9″	8′-8″	35′-7″	
500,000	50′-0″	15′-0″	14′-6″	9′-8″	39′-2″	
600,000	55′-0″	14′-4″	14′-0″	10′-0″	38′-4″	
750,000	60′-0″	15′-11″	12′-7″	11′-6″	40′-0″	
1,000,000	65′-0″	21′-8″	15′-9″	11′-0″	48′-5″	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H
20,000	15	10 9	16 2	
25,000	15	14 7	19 11	Any
30,000	17	12 7	19 0	height
40,000	19	13 1	20 6	from
50,000	21	13 1	21 1	15′ 0″
60,000	24	10 1	20 3	to
75,000	24	15 1	23 10	40′ 0″
100,000	28	13 5	23 7	in
150,000	28	14 2	24 7	multiples
200,000	36	15 1	29 2	of
250,000	38	17 3	33 3	5′ 0″
300,000	38	23 11	38 3	

Table V—Toroidal Bottom Tanks



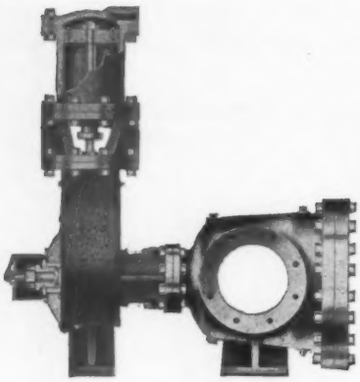
Capacity in U. S. Gallons	Tank Diameter (D) when h = 10′ 0″ and V = 20′ 0″ ft.	in.	V = 25′ 0″ ft.	in.	V = 30′ 0″ ft.	in.	V = 35′ 0″ ft.	in.	H
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built
1,500,000	115	2	102	9	93	9	86	8	to
2,000,000	132	8	118	5	108	0	99	11	Order
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Height ft.	in.
50,000	20	21	6
60,000	22	21	6
75,000	24	22	6
100,000	26	25	6
150,000	30	28	9
200,000	34	29	9
250,000	38	29	9
300,000	42	29	3
400,000	46	32	6
500,000	50	34	6
750,000	60	35	9
1,000,000	70	35	0
1,500,000	80	40	3
2,000,000	95	38	3
2,500,000	110	35	6
3,000,000	120	35	9
4,000,000	130	40	9

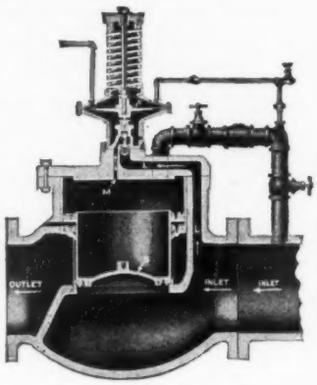
GOLDEN-ANDERSON VALVE SPECIALTY CO.

1350 Fulton Bldg.
PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.



ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24″.

CUSHIONED FLOAT VALVE

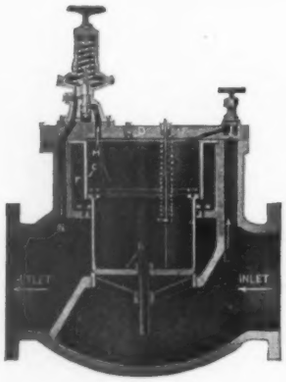
Automatically maintain uniform water levels in tanks, standpipes, etc.

Instantly adjusted to operate quickly or slowly.

Cushioned by water and air, sizes ½ to 24″.

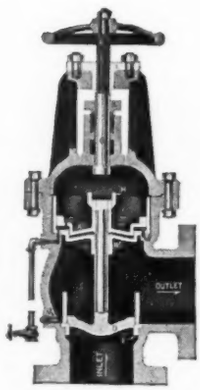
CONTROLLING FLOAT VALVE

Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24″.



WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24″.

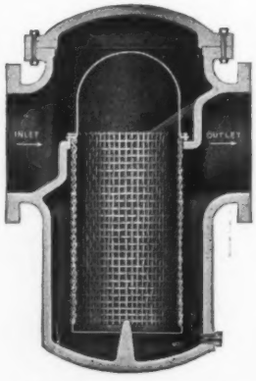


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12″ in angle, globe or elbow patterns.

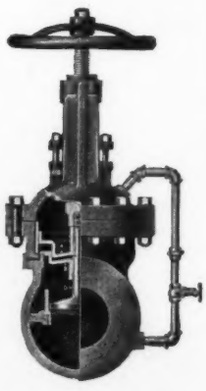
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24″.



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12″ sizes.



CATHODIC PROTECTION

For Water Tanks and Submerged Metallic Parts

By EARL E. NORMAN, Superintendent
Department of Public Utilities, Kalamazoo, Michigan

DURING the past few years there has been a great deal of interest shown in the process of electrically controlling internal corrosion of water tanks. I have been asked to outline some of the principles involved, and to indicate some of the results that may be expected from such a process, as well as gather information from representative installations of the process.

Definitions

In order to prevent any misunderstanding, it might be well to set forth certain definitions. The word "Cathodic" refers to or is related to the word "cathode," which is a fundamental part of an electric cell. In fact the speaker believes this treatise can be better understood if we consider the tank and associated parts, which we will describe, as a large electric cell. Now, a cathode is defined in electro-chemistry as that pole or electrode in an electrical wef cell toward which the electricity flows through the liquid in the cell, the latter being designated the electrolyte. It is the electrode by which the electric current leaves the cell. In our case the cathode is the tank body itself, and of course it is this cathode that we wish to protect. (Incidentally the electrode by which the electricity enters the electrolyte is called the anode.)

The word "protection" immediately gives rise to the question, "Protection against what?" The answer is protection against corrosion, which is basically electro-chemical in the final analysis, as will later develop.

It then becomes necessary to define corrosion. We could spend several minutes, even perhaps hours, on this one subject. Mr. U. R. Evans in "The Corrosion of Metals" has given a definition of corrosion in very few words; and is, I believe, quite to the point. He says that while the study of metallurgy is the study of "making of metals," a study of corrosion is a study of the "unmaking of metals." In other words, corrosion is the process of the return of metals to their native state. In the case of steel or iron this is the oxide or the hydrous oxide.

As to the term "Water Tanks," of course we all know what a water tank is. Nevertheless, in order to narrow this paper down to its precise application, we well define a water tank for the purpose of this paper as a steel or iron tank. Tanks of concrete and non-ferrous metals will not be considered in this paper.

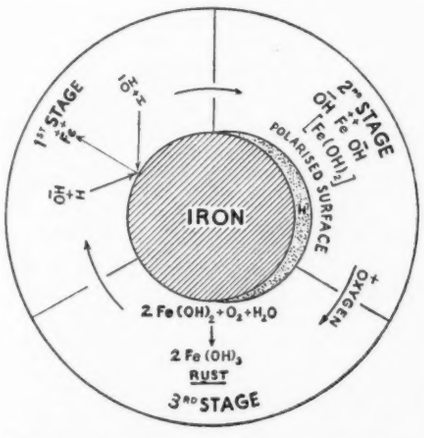


Fig. 1. The Progress of Corrosion and Rusting, Graphically Pictured.
The 1st stage is that of solution and ionization of the iron in which small D. C. current flow is produced—such flow being subject to reversal by opposing current input. The 3rd stage is that of oxidation by dissolved oxygen and visible rusting. Rust is the return of metallic iron to its native state, the oxide, and is in reality nature's "scab" that forms over the "sores" of corrosion.

Theory of Corrosion

We could spend a lot of time going into the theories of corrosion. These theories involving as they do, not only Ohms Law, Faradays Law and Electrolysis, but also atoms, ions, electrons and a lot of other "ons" are liable to get one into "deep water," particularly one whose knowledge on some of these things is as limited as is your speaker's. After all, I believe we are not so interested in theory, but are very much interested in exactly what happens. Therefore, I am going to pass over the theory and go immediately to the problem of what happens in such situations.

The progress of corrosion of iron and the three stages from metallic iron to rust or tubercles is rather effectively pictured in the accompanying graphical sketch of the corrosion cycle.

Practice

We are all more or less familiar with ordinary electro-plating processes. For example, in case of copper plating, an article is placed in a copper solution and an electrode of pure copper (the anode) is also placed in the solution. A direct current enters the cell by means of this anode and passes through the copper solution (electrolite) and onto the article which is to be plated. The article is the cathode and receives the copper transported by the flow of introduced current. In this process the anode passes into solution at a rate determined by the direct current input.

Another example is familiar to all of you who have ever operated a water system in a city blessed with street cars. You of course are familiar with the fact that the destruction of water mains by electrolysis occurs only at points at which electricity *leaves* the main. At such points the water main is an anode. On the other hand, at places where the electric current goes onto the mains no damage is done.

These two very familiar examples are given simply to refresh our memories because these two examples are but examples of the same process in which we are interested in this discussion.

Application

Although one would think by the large number of inquiries on the subject of cathodic protection of water tanks this must be a brand new invention, such is not the case. The same basic idea has been used on pipe lines for many years, the first application having been made in about 1930. In the case of pipe the protection is against external corrosion (soil pitting) and not internal as is the case with water tanks.

While there are many installations of pipe lines protected by the cathodic method of corrosion control, the two that I will now mention will serve as examples.

A pipe line of interest is one in Louisiana about 80 miles long. A five-mile section was especially studied for purposes of determining the effectiveness of electrical protection. On this five-mile section during the six months immediately preceding the application of the protection an average of 5.5 pit leaks per mile per year developed. It was not anticipated that the application of cathodic corrosion control would immediately reduce the leaks.

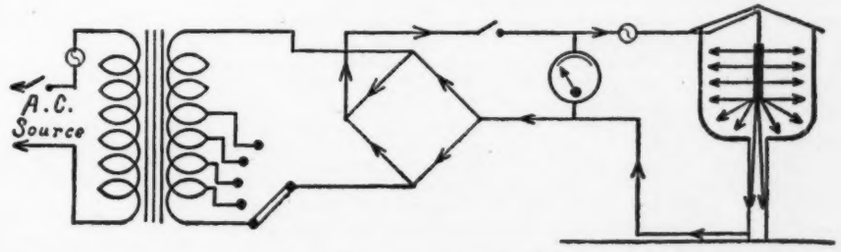


Fig. 2. A Schematic Sketch of Cathodic Protection.
This "flow sheet" indicates the conversion of A. C. to D. C. current in passing through the rectifier (left); flow as D. C. through the suspended anode in the tank (right) and its travel radially through the electrolyte (water) as a plating current to the cathode (tank walls). The ions of hydrogen and metals in general (notably calcium) are plated out on the tank surface or on any other submerged metallic surface which has a conducive ground connection.

In fact, it was thought that perhaps the number of leaks might actually increase for a time after the process was started. This was found to be the case, for during the six months immediately following the application of cathodic corrosion control, an average of 8.8 leaks per mile per year developed. The theory is that the cathodic corrosion control removed some of the accumulations of rust from the pits which were already badly developed, and so weakened the pipe wall that additional leaks actually showed up. During the next twelve months, however, the average number of leaks dropped to 0.2 leaks per mile per year. After the system had become thoroughly established and in operation beyond any question of doubt, the protection was shut off to see what would happen. During this first six months, it was expected that the number of leaks would not be serious. This was found to be the case because only an average of 0.8 leaks per mile per year developed. The cathodic corrosion control was, therefore, placed back in operation immediately and the leaks tapered off to practically zero again.

Another interesting installation was the application of cathodic corrosion control to the pipe lines of Treasure Island at the World's Fair in San Francisco. This installation and results are presented in a detailed account by Mr. Charles E. Lee in the A.W.W.A. Journal of February, 1940. These pipe lines are laid through "made" ground, which is extremely corrosive. The first failure occurred ninety days after the pipe was placed in service. During the next seven weeks forty-eight failures occurred. Thereupon cathodic corrosion control was applied to all underground pipe structures on Treasure Island with results quite comparable to those indicated previously for the pipe line in Louisiana. The World's Fair authorities estimated that if no cathodic corrosion control had been applied 518 leaks would have developed during the thirty weeks of construction previous to opening the Fair, rather than the actual number of 146 leaks, and most of these 146 leaks occurred before the application of the inhibiting process.

Application to Tanks

The application of cathodic corrosion control to tanks is in theory quite like the application of cathodic corrosion control to pipe lines except that in the case of tanks the aim is to protect the container against internal corrosion, that is, corrosion from the water itself, while in the case of the pipe lines the aim is to protect the container against external soil corrosion. Therefore the application of cathodic corrosion control in tanks should be a much simpler process, and subject to more exact observations and adjustment if required.

Although I indicated a few minutes ago that I would pass by the theory, I think it would be well to reconsider very briefly just a little theory involved in the application of this method of control of corrosion in tanks. If we set up a cell consisting of a suitable anode in water, in a tank, and if we then circulate direct current of a suitable voltage and amperage from the source of supply into the anode, thence to the water and on to the tank, a plating action will take place quite similar to that described previously relative to electro-plating processes. Instead of plating out copper, silver or some other metal, however, in this case hydrogen gas in the form of hydrogen ions will plate out onto the surface of the cathode the tank walls. Calcium and other positive ions (depending upon the mineral content of the water) will also plate out against the surface of the tank in the same manner. As long as this process is kept up, and as long as the film of hydrogen, calcium, etc., remains unbroken, rusting and other forms of corrosion on the tank surface will not take place.

It is therefore only necessary to provide the equipment to keep this process in operation. In practice, this consists of one or more electrodes of a suitable material (usually either stainless steel or graphite) suspended from the roof of the tank into the water, but insulated from the tank. These are the anodes. There is also provided a source of current supply. This usually consists of a transformer, a dry type of rectifier and suitable controls so that the voltage and current can be adjusted to the needs of the particular installation. What determines the current required is the mineral content of the water and distance between the anode and the tank walls; also to what extent the original protective coating on the tank interior has disappeared. In the case of very badly corroded tanks the current flow may be considerable in the beginning until the protective film has deposited sufficiently to retard current flow.

These devices are connected so direct current from the rectifier runs from the rectifier to the anode through the water onto the tank, thence back to the rectifier. (See flow diagram.)

Comporative Costs Important Consideration

No matter how unique or interesting a piece of apparatus might be, it can hardly be justified unless economy is shown by its use. If capital investment is necessary, the fixed charges incurred by such capital investment must be considered. If operating costs are incurred, these must also be considered. In the case of cathodic corrosion control, both of these costs are incurred. The capital cost, when once invested, however, is not repeated year after year. And, strangely enough, in many cases the capital cost of cathodic corrosion control equipment is less than a single paint job. The operation costs are also very nominal. The equipment consumes so little power each month that in many cases the power cost is within the minimum charge for the use of electric service.

In one case (a 350,000 gallon tank) the cost of painting the interior of the tank below the water line would have been $700.00, while the capital cost of cathodic corrosion control was only in the neighborhood of $400.00. In like manner, a certain 750,000 gallon tank was equipped with cathodic corrosion control equipment at a cost of a little over $400.00, whereas the cost of painting the inside surface of that tank below the water line would have been $950.00. In the case of this 750,000 gallon tank, assuming a paint job to last five years, would make the cost of paint $190.00 per year. If we assume a fixed charge to cover taxes, depreciation and maintenance on the cathodic control unit at fifteen per cent, we have a fixed charge of $60 00 per year, to which must be added the charge for electric service amounting to $12.00 per year, or a total cost of $72.00 per year. This leaves an annual profit of $118.00 per year or 29.5 per cent on the investment.

Convenience Also a Consideration

This financial saving or profit is not the only advantage, however. We should also keep in mind that we are: (a) preventing the tank itself from disintegrating, which after all is even more important than the financial savings, and (b) making it unnecessary to take the tank out of service for periodic painting. Since painting must be done during the warmer months, when the tank is most needed in service, the matter of removing a tank from such service is oftentimes a serious problem, and is the most prevalent reason for deficient tank maintenance.

Conclusion

In conclusion let me repeat that cathodic corrosion control is not new. It is a very old principle. In fact, it is very strange, in the writer's opinion, that it has not been applied many years ago. However, there are approximately 600 water tanks in the United States at the present time to which this treatment has been applied.

Replies to a questionnaire, circulated by the Pittsburgh-Des Moines Steel Company, indicate an overwhelming majority in favor of cathodic corrosion control. Replying to the question, "Does the electric rust prevention device protect the tank interior as well as paint or other coating material?" sixty-eight per cent said, "Yes," seventeen per cent did not answer the question, eight per cent could not say, but nobody replied in the negative. As a matter of fact, the purveyors of cathodic protection equipment guarantee that the answer is—"Yes."

In response to the question, "If you were building a new water tank, would you specify that the paint be omitted on the interior below the water line?" seventy-five per cent replied "Yes," twenty-five per cent did not answer the question, but nobody replied in the negative. This questionnaire revealed that the original capital cost of the equipment ranged from $198.00 to $525.00, while likewise the annual maintenance cost ranged from $3.00 per year to $25.00 per year. It is apparent that the answer to the current cost is this—the more the tank is in need of protection the greater the current costs in the early period of application. The less the corrosivity of the water, or the better the condition of the original protective coating, the lower the current requirement and operating costs.

There is no question but that the water works industry has been presented with a very useful and inexpensive device. There is no question as to its economy and, if the electrodes are mounted in such a manner as to preclude difficulty from freezing, it is the writer's opinion that this device will receive the wholehearted support of the water works industry and enjoy nation-wide adaptation.

In closing, I wish to extend my thanks and appreciation to the many individuals and organizations who have rendered valuable assistance in the preparation of this paper.

Acknowledgment—This article is, for the most part, portions from a paper presented by Mr. Norman before the 1940 *Convention of the American Water Works Association. The sketches are those illustrating an article on "Cathodic Protection," by Wm. D. Loreaux, which was reproduced in the Reference and Data Number of "Water Works and Sewerage" for* 1940*—Ed.*

ELECTRO RUST-PROOFING CO.

29 West Apple St. **DAYTON, OHIO**

WHAT IT IS

The RUSTOP System is the cathodic system of preventing underwater corrosion of steel storage tanks. It consists of a rectifier, anodes of suitable material, the necessary meters, wiring and other incidentals.

WHAT IT DOES

The RUSTOP System definitely inhibits the corrosion of steel under water in elevated tanks, standpipes, hot water storage tanks, filter plants, condensate tanks and similar vessels affected by oxidation.

The RUSTOP System cleans off all rust, scale and corrosion products, and protects the metal from any further oxidation. This protection continues as long as the System is used. On new tanks, the protection starts as soon as the water is first put in the tank. The tank walls, bottom and riser will remain free of any corrosion.

HOW IT WORKS

The RUSTOP System maintains the tank in a cathodic condition as long as the System is used. Before an installation is made on any tank all factors such as size and shape of tank, character of water, method of use, etc., are taken into consideration. The RUSTOP System is then engineered for that specific tank. A long-lived rectifier (some on similar service have lasted 25 years) of the proper size and type, with the size, number and types of anodes for the right distribution are recommended. It is only by such engineering that complete protection, free from localized corrosion, can be obtained.

TYPES AND SIZES OF TANKS

The RUSTOP System is installed on tanks from a few hundred gallons capacity to six million gallons capacity, of diameters up to 120 ft. All types of tanks are included: flat bottom, spherical, hemi-spherical, spheroids, ellipsoidal, hemi-ellipsoidal, double ellipsoidal, toroidal, conispherical, standpipes, reserves, surge tanks, and tanks of special design made for advertising purposes. Included also are installations made on pressure vessels and hot water tanks of vertical and horizontal designs.

Installations are also made on dual service tanks arranged for daily use and fire protection; industrial tanks used for fire protection purposes; rotating filters; filter beds and clarifiers.

APPROVED

The RUSTOP System has been thoroly investigated and the results checked by the Associated Factory Mutual Insurance Companies with headquarters in Boston, Mass. As a consequence, the Factory Mutual Laboratories under the direction of the Inspection Department have issued Report No. 10668, titled: "Examination and Test of Cathodic Method of Corrosion Prevention of Steel Water Storage Tanks." *This is the only cathodic System bearing the approval of the Factory Mutual Laboratories or any similar organization.* A copy of this report in full will be sent free to anyone interested.

USERS

The following are representative users of the RUSTOP System: villages, municipalities, counties, state institutions, Federal agencies, arsenals and powder plants, railroads, industrial plants, public utilities and paint manufacturers. Geographically, these extend from Canada to California and from Maine to Texas.

REPEAT PURCHASES

Several users have bought repeat installations after the first one had proved its worth. Among these are: The Chrysler Corporation, The Indianapolis Water Co., Eli Lilly Co., Owens-Illinois Glass Co., Great Western Sugar Co., Jamaica Water Supply Co. Long Island, Dayton Power and Light Co., Bridgeport Hydraulic Co., American Viscose Co. and a number of others. Names of representative users will be supplied gladly on request.

WHAT IT COSTS

The cost of the RUSTOP System depends on the size and shape of the tank, etc. In the vast majority of cases, the first cost is less than what it would cost to paint the tank twice. And besides, use of the tank is not interfered with for one moment. The water is not contaminated nor is the taste affected.

Current consumption is not a great item. Since the voltage and amperage are low, the cost may vary from a few cents a month to a few dollars per year, depending on the size of the tank.

If you attend the Convention at Toronto, please look us up. We shall be glad to explain the RUSTOP System to you in person. Or, write for bulletins and a Tank Data sheet. Supply us with the information asked for and we will be glad to quote vou on the installation on your tanks.

The RUSTOP System

. . . a definite saving to Water Tank Owners

JOHNS-MANVILLE

Executive Offices: 22 E. 40th Street, New York, N. Y.

Offices in all large Cities

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TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

TRANSITE PRESSURE PIPE . . . *a brief discussion of how this asbestos-cement pipe can help you provide more efficient water service at lower cost—*

A SUMMARY OF TRANSITE PIPE'S OUTSTANDING CHARACTERISTICS

•

MADE OF ASBESTOS AND CEMENT — Transite Pipe is built up under tremendous pressure on a polished steel mandrel to form a homogeneous structure of great strength and uniformity.

EACH LENGTH ACCURATELY TESTED — Every length of Transite Pipe is individually tested to four times its specified rating in a hydrostatic test machine. In those sizes where flexural strength is important, each length of pipe is also subjected to a beam test with the load applied at the one-third points of the pipe span.

HIGH CARRYING CAPACITY — Because of its smooth interior, Transite Pipe provides an unusually high flow coefficient, C=140.

CANNOT TUBERCULATE — Because it is non-metallic, Transite Pipe can never rust or tuberculate. As a result, delivery capacity can never be reduced by this internal corrosion — expensive cleaning to remove tubercules is never required.

HIGHLY RESISTANT TO CORROSION — One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is high resistance to corrosion — inside, outside and all the way through. Thousands of installations attest to Transite's durability in all kinds of soils.

TIGHT JOINTS — Composed of a Transite sleeve and two rubber rings, the Simplex Couplings used in Transite lines provide unusually tight, yet flexible joints.

UNIFORM STRENGTH — Transite Pipe is made in a wide range of sizes and in pressure classes of 50, 100, 150 and 200 lbs. Its method of manufacture and test procedure assure absolute uniformity in the finished pipe, thus permitting engineers to take full advantage of all pressure classes to meet varying requirements along the line.

EASILY INSTALLED — Transite Pipe is furnished in long, 13-ft. lengths. Relatively light in weight, they are easily handled and installed. Simplex Couplings are asembled quickly and easily, even in wet trenches — a simple hydraulic coupling puller is the only tool required.

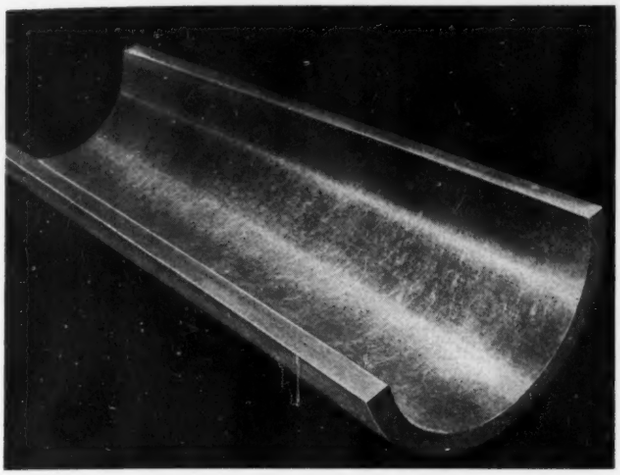
IN SELECTING a water pipe — whether for an extension or replacement of existing lines or the installation of a complete new system—careful consideration should be given to the basic factors contributing to the economic life of the pipe. For example:

DELIVERY CAPACITY . . .

Waterworks engineers generally agree that a water main, even though it remain structurally intact, may completely outlive its economic usefulness over a period of time. This point is reached when the pipe will no longer carry, economically, a sufficient volume of water to meet demand. Such a condition may arise from characteristics inherent in the pipe itself, from increased demand or from a combination of these two causes. Thus, in designing water systems, the engineer is faced with the responsibility of anticipating and solving these problems.

To compensate for expected reductions in carrying capacity, specifications often call for

One of the hundreds of American Municipalities, where Transite Pipe is providing unusually efficient, economical water service. Transite's speed of assembly reduces the time trenches must be open—minimizes traffic congestion and inconvenience to business.



Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.

Over 62,000 feet of 10-inch to 30-inch Transite Pipe were used on this water collection and transmission system. Because of its light weight and speed of assembly, the pipe was laid as fast as the trench was opened.

larger sizes of pipe than would otherwise be necessary. However, there is another, less expensive solution. In J-M Transite Pipe, engineers find basic advantages that permit them to specify the most economical pipe sizes with full assurance that delivery capacity will not be reduced by tuberculation, the internal corrosion which, even when present in relatively small degree, greatly reduces the carrying capacity of ordinary pipe.

Transite Pipe is an asbestos-cement product. During manufacture, it is built up on a polished steel mandrel that imparts unusual smoothness to the interior wall. Its flow coefficient is conservatively estimated at C = 140. This means that Transite water lines start with an exceptionally high carrying capacity.

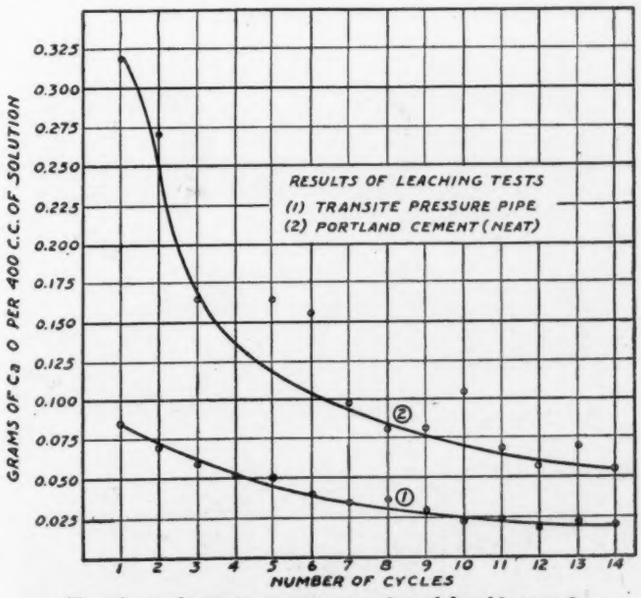
Transite's freedom from tuberculation means that pumping costs stay low, for pressures need not be increased to compensate for a steadily decreasing flow coefficient and resulting loss of head in the line. Not only does this advantage provide worthwhile operating economies, but in many cases it also permits the use of smaller diameter pipe with resultant savings in all the numerous items that go to make up the original cost of completed water lines.

SOIL CORROSION . . .

Broadly speaking, most soil corrosion engineers agree that there are two principal forms of soil corrosion — chemical and electrochemical.

Chemical corrosion is caused by the action of acids and salts encountered in the soil. While neat cement contains an appreciable amount of free lime which may be leached out by these active agents, Transite Pipe, due to its curing process, has the free lime set as insoluble silicates. A comparison of the two curves in the diagram below shows the high degree of insolubility of Johns-Manville Transite Pipe. It is for this reason that Transite is so highly resistant to all forms of chemical corrosion.

Electro-chemical corrosion is caused by the electrolytic action between ordinary pipe and materials in the soil. This action is similar to that of a simple electric cell. In this case, the materials in the soil represent the positive pole; the soil moisture, the electrolyte, and the pipe wall serves as the negative pole. The current generated passes from the metal pipe to the positive



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

JOHNS-MANVILLE

pole and causes a gradual disintegration of the pipe structure.

With Transite, however, this condition can never occur, because being non-metallic, Transite is a non-conductor—therefore absolutely free from electrical corrosion. Furthermore, this asbestos-cement pipe is immune to electrolysis caused by stray electric current from high voltage lines, streets, railways, etc.

The successful performance of Transite Pipe in all kinds of soil and under many varying climatic conditions provides practical proof of its high resistance to corrosion—inside, outside and all the way through.

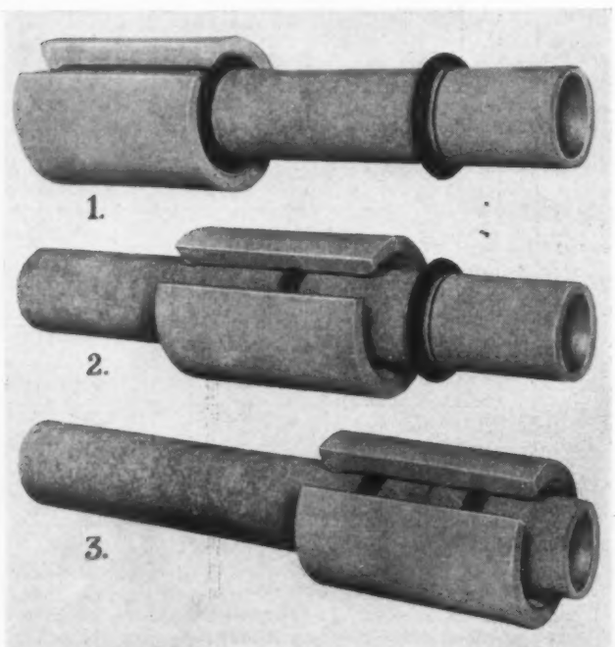
JOINT LEAKAGE . . .

Numerous surveys have shown that leaky joints are responsible for a considerable portion of total water losses from underground mains. Generally recognized by waterworks men as a serious problem, joint leakage not only results in a direct waste of water but, by washing away supporting soil, frequently causes pipe to fracture under traffic and earth loads.

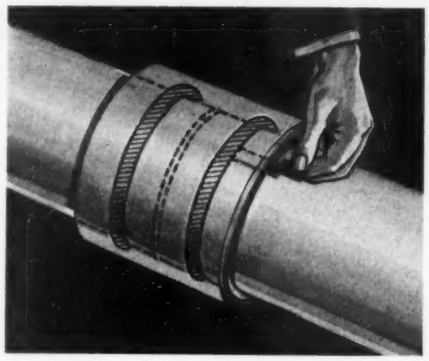
Much of this trouble is caused by the fact that the ordinary rigid joint, even though perfectly made by skilled workmen, may open up when subjected to vibration or settlement after the line is in service.

Such potential losses are minimized with a flexible joint. And that is the principle upon which the Simplex Coupling, employed in assembling Transite Pipe, was designed. Consisting of a Transite sleeve and two rubber rings, it forms a tight joint that stays tight in service. Its flexibility compensates for vibration and for vertical, longitudinal and lateral movements to which the pipe may be subjected underground. Depending upon the size of the pipe, a deflection of as much as 5° is possible at each joint.

From a practical standpoint, the less skill required in assembly, the less the danger of defective joints in the field. The dependability of the Simplex



Simplex Couplings Assembly (1) at start of operation (2) sleeve pulled over one ring, (3) final position, sleeve centered over joint.



With Simplex Couplings tightness of the joint can be determined from the outside as soon as the pipe is laid. A thin steel blade, slipped under the lip of the sleeve, checks the position of the rubber ring. If the position is right, the joint is tight.

Coupling is due primarily to these distinctive features:

1. It is actually a pre-fabricated, "packaged" joint. The ends of the pipe and the inside of the coupling are machined to exact dimensions. The rubber rings are precision-made and subjected to rigid inspection before shipment. Joints are assembled cold—no pouring, caulking or heating equipment is needed. A simple hydraulic coupling puller, loaned by Johns-Manville without charge, is the only tool required for assembly.

2. The effectiveness of the joint does not depend on the individual skill or training of the workmen. So simple is the operation that perfect Simplex joints can be made quickly and economically even by unskilled crews.

Made of Permanent Materials. The Transite sleeve, like the pipe itself, is made of asbestos and cement and has the same high degree of resistance to all forms of corrosion. The rings, made of the highest quality rubber, are carefully cured and specially compounded with anti-oxidents and properly graded non-hygroscopic fillers to assure permanence in water service.

INSTALLATION . . .

One of the major factors contributing to initial cost of a pipe line is the time and equipment required for installation.

Transite Pressure Pipe offers primary advantages that help speed up installation and cut costs. The long, 13-ft. lengths are relatively light in weight. Two or three men can easily lower 8 inch pipe into the trench by hand. In fact all but the very largest sizes can be handled without the use of mechanical equipment.

Simplex Couplings are assembled cold just as they are received from the factory. Wet trenches present no problem for no heating or caulking equipment is required. And the complete assembly is completed in much less time than required by ordinary types of joints.

WRITE FOR COMPLETE DETAILS

A detailed discussion of the economic factors contributing to efficient, low-cost water lines is given in the Transite Pressure Pipe Brochure, TR-11A. The 76-page "J-M Pipe Installation Manual," D. S. 332, outlines effective methods of installing water lines and includes much more data on Transite Pipe and the Simplex Coupling than was possible to include on these pages. For your free copy of these two books, write to Johns-Manville, 22 East 40th Street, New York, N. Y.

JOHNS-MANVILLE

AND IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

Transite Sewer Pipe offers fundamental advantages that help reduce the cost of sewer line construction, maintenance and operation.

Pressure Sewer Lines are very similar in operation to water lines and must meet the same general service requirements. In addition, the pipe must be highly resistant to the corrosive action of the sewage. Transite Sewer Pipe, which is made of the same durable asbestos-cement composition as Transite Water Pipe, meets all these requirements and provides highly satisfactory service in systems of this type. Gravity Sewer Lines, however, offer a number of specialized problems that must be considered separately. For example:

INFILTRATION—

It has been authoritatively estimated that as much as 25% of the contents of the average sewer is ordinary ground water that enters the system by infiltration through the joints. And it costs practically as much to treat this water at the disposal plant as it does to treat sewage itself. Furthermore, in many cases, engineers must allow for this huge quantity of water by specifying a larger diameter pipe than would otherwise be necessary.

With Transite Sewer Pipe, however, the infiltration of ground water presents no serious problem. Transite's long 13-ft. lengths cut down the number of joints in the line, thus reducing the danger of infiltration right at the start. The poured sleeve joints employed in Transite lines are unusually tight and stay tight in service. The jointing compound is the highest quality, unfilled asphalt which, when set, provides a strong, flexible joint that is highly resistant to cracking or shrinkage. As a result, Transite Sewer Pipe lines have considerably less infiltration than that allowed by most specifications.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

CARRYING CAPACITY

One of the most important factors in any sewer line is carrying capacity. All other things being equal, the relative carrying capacity of two or more types of pipe is best indicated by their flow coefficient. If, for example, the inside of the pipe is rough and uneven, the flow velocity is low and carrying capacity is greatly reduced. A smooth pipe, however, has a high flow velocity and a correspondingly high carrying capacity.

Transite Sewer Pipe has an unusually smooth interior surface, its conservative friction coefficient when installed at the usual sewer pipe grade is N=.010. This high carrying capacity results in savings that can be taken in one of two ways. Flatter grades may be employed during installation — reducing the depth of the trench and making installation a faster, more economical job. Or, when the usual sewer pipe grade is maintained and deep trenches present no problem, Transite's high flow velocity often makes it possible to use a smaller diameter pipe without reducing the desired carrying capacity of the system.

OTHER CONSIDERATIONS

Resistance to corrosion, structural strength and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its asbestos-cement composition and its unusually low free lime content, Transite Sewer Pipe is highly resistant to the corrosive action of all types of industrial and domestic sewage — inside, outside and all the way through.

Transite Sewer Pipe is furnished in sizes from 4" to 36" in class I, and from 10" to 36" in Class II. Wall Thickness and structural strengths are rigidly controlled during manufacture, permitting the accurate, economic selection of the right class of pipe to meet the particular soil loads encountered.

The long 13-ft. sections in which Transite is furnished eliminates many of the difficulties in installation common to ordinary short length sewer pipe. Relatively light in weight, these long lengths cut down handling costs. More footage may be carried per truck load to the trench and fewer men are needed to install the pipe. These long lengths also reduce the number of joints that must be made and thus save considerable time and labor. In addition, long lengths greatly facilitate laying the pipe to an accurate grade.

It will pay you to get full details about this modern sewer pipe. Write for brochure TR-21A. Johns-Manville, 22 East 40th Street, New York, N. Y.

JOHNS-MANVILLE JM PRODUCTS

ESTABLISHED
1905

LOCK JOINT PIPE CO.

Ampere, N. J.

REINFORCED CONCRETE PIPE

PRESSURE SEWER SUBAQUEOUS CULVERT

Manufactured with Local Material and Local Labor at the Job Site

WHY YOU SHOULD SPECIFY LOCK JOINT REINFORCED CONCRETE PRESSURE TYPE

Speed and Economy of Installation

The National Defense Program demands speed and dependability of construction. The most effective way to speed up completion of water supply lines for industry, municipalities or defense projects is to place the entire responsibility for construction and installation in the hands of one competent contractor.

The Lock Joint Pipe Company is prepared, by virtue of long and varied experience, to assume such entire responsibility. Since 1914 this company has fabricated and installed Lock Joint Reinforced Concrete Pressure Pipe for many of the largest water supply lines in this country.

This experience as Manufacturer and Contractor has resulted in substantial economies of time and money to municipalities and industries.

Types of Pipe

Cylinder Pipe: Water-tight steel cylinder with steel joint rings welded to it at each end, and a surrounding cage of reinforcing steel. Lined and coated with rich, durable concrete. Sizes 16″ to 150″.

Bar Pipe: Reinforcing consists of steel cages. Sizes 16″ to 150″.

Centrifugal Pipe: Bar type pipe cast centrifugally in horizontal molds.

Permanent Advantages

Economy: Low First Cost; Low Maintenance Cost; Low Operating Cost; Minimum Depreciation. Local labor and materials are largely used in the construction and installation.

High Initial Carrying Capacity: Smooth interior with filled in joint spaces assures high carrying capacity. Actual tests on many new lines showed "C" = 135 to 154 (Hazen-Williams).

Sustained High Carrying Capacity: Lock Joint Pipe is not subject to Tuberculation, Corrosion or Electrolysis. Again actual tests on lines in service, some as long as 18 years, show values of "C" equal to or higher than when the pipe was installed.

Water-Tightness: Lock Joint Pipe joints are thoroughly water-tight by test. Pipe lines regularly show measured leakage less than 10 per cent of that allowed in contracts.

Strength: Experience throughout the country shows a complete absence of broken pipe or leaky joints.

Long Life: Engineers have stated that 100 years is a conservative estimate of the life of Lock Joint Pipe.

Types of Joints

Rubber: The sealing element consists of a special composition rubber gasket tightly compressed between the steel joint rings, thus completely protecting it from any deteriorating element. Used on cylinder, bar and centrifugal pipe.

Lead: The sealing element consists of a fibre-filled lead gasket hand-calked from inside the pipe after laying and backfilling. Used on cylinder and bar pipe.

Ball and Socket: Spherical concrete surfaces held together by projecting tie rods set in mortar after pipe is laid. For subaqueous installations.

Types of Lock Joint Pipe Lines

Pressure Pipe Lines for Water or Sewer

Cylinder or bar type pipe with either lead or rubber expansion joints. Both joints are self-centering, permanently water-tight, permit expansion and contraction due to changes in temperature and have the necessary flexibility to allow deflection of the joints resulting from normal earth movements.

Low Pressure Pipe Lines for Water or Sewer

Bar or cylinder pipe with Rubber or Lead joints.

Our nearest office will give complete information regarding manufacture and installation of pressure pipe lines for water supply, sewers, subaqueous intakes or outfalls, as well as standard types of sewer, culvert, and drain pipe.

Subaqueous Water and Sewer Lines

Bar or cylinder type pipe with Rubber Gasket or Ball and Socket joints: Pipe sections clamped together with heavy bolts passing through steel castings molded into pipe ends and welded to reinforcing rods. 20″ to 108″ diam. Self-centering, flexible, expansion joints easily assembled by divers.

BRANCH OFFICES

Denver, Colo.	Chicago, Ill.	Kenilworth, N. J.
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PIPE LINE FRICTION COEFFICIENTS

A Summary of the Findings of the Committee on Pipe Line Friction Coefficients

The voluminous report embracing data collected and compiled by the above committee has been printed in the September, 1935, *Journal* of the New England Water Works Association, and is available in the form of reprints.

A summary of the scope of this report and the conclusions presented therein are reviewed in the following abstract, prepared by E. T. Killam, chairman of the Committee.

The general conclusions drawn from the data submitted to the Committee are as follows:

1. The average *actual* loss in capacity of tar-coated cast-iron pipe after 30 years of service, based on a total of 473 tests in 19 different systems, was 52 per cent.

The loss *predicted* in the Williams-Hazen tables for mains of similar age and diameter (average 20.5 in.) and for "average soft unfiltered river water" is 32.3 per cent.

2. Based upon the data available to the Committee, the Williams-Hazen age-coefficient relation is applicable primarily to large-diameter mains carrying relatively inactive water.

3. For small-diameter mains carrying active water, the actual *loss* after 30 years may be twice the Williams-Hazen *predicted* loss.

4. Other factors being equal the data show marked correlation between pH value of water carried and rate of capacity loss, average conditions reported indicating for supplies with a pH value of 6.5, twice the loss observed in supplies with a pH value of 8.0.

Scope of Report

The principal objective of the report was the presentation of heretofore unpublished data upon friction coefficients of tar-coated cast iron pipe, with particular reference to the age-coefficient relation for this type of pipe, and the effect of water quality upon rate of capacity loss.

The report also contains sections dealing with various remedial measures for reducing and preventing loss of capacity, including discussions of coefficients of cement and bitumastic-enamel linings; methods of lining pipe in place; corrective treatment of the water carried, and pipe cleaning.

Certain other subjects not involved in the question of discharge coefficients of tar-coated cast-iron pipe, but falling within the general scope of the subject of "Pipe Line Friction Coefficients," have been presented in the form of appendices, in order that this additional information might be made readily available in a single report.

Precision

The Committee has endeavored to compile mass data of reasonable precision; obviously, the widely varying conditions found, and the many factors involved, could not be generalized upon any other basis. Accordingly, while the collection of data was in no way restricted to sources affording "laboratory" precision, the material presented includes only such data as have been considered to fall within limits of reasonable precision set by the Committee.

This policy of precision applies particularly to the presentation of various "trend curves," which is the designation adopted for expressing the age-coefficient relation. These "trend curves" in which values of C have been plotted against the age of the pipe in years, have been presented only in cases for which numerous tests of reasonable accuracy were available.

In considering these trend curves it should be emphasized that the results represent actual field tests and accordingly include all incidental losses due to irregular line or grade, and due to fittings or special castings.

Use of Williams-Hazen Coefficient "C"

The Williams-Hazen formula has been used throughout the report for the determination of coefficient values, and all values of C refer to the Williams-Hazen coefficient in the following formula:

$$v = Cr^{0.63} s^{0.54} 0.001^{-0.04}$$

v = Velocity in feet per second
r = Hydraulic Radius in feet
s = Hydraulic slope in feet per foot
C = The Williams-Hazen Coefficient

In translating values of C to equivalent capacity loss, it is convenient to bear in mind that capacity is directly proportionate to the value of C. With slope and diameter fixed, a drop in the value of C from 130 to 65 consequently involves an equivalent capacity loss of 50 per cent.

Coefficients of Tar-Coated C. I. Pipe

Tar-coated cast iron pipe has been more widely used in water works practice than any other type of pipe, and a discussion of coefficient values with this type of pipe was accordingly selected for the first and principal subject of the report.

In considering the existing condition of old pipe, and attempting to determine the loss of capacity with age, selection of a value of C for new pipe becomes a fundamentally important assumption. The values of C for new tar-coated cast iron pipe adopted in the report are as follows:

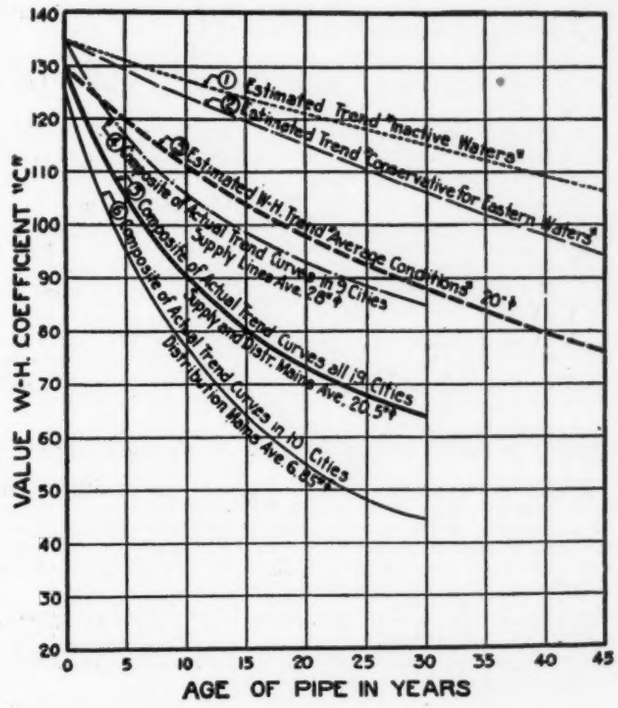

Fig. 1.—Summary of estimated and actual trends of Age-Coefficient Relation for Tar-Coated Cast-Iron Pipe.

Curves 1 and 2 are based on data for steel pipe (U. S. Dept. of Agriculture, Bull. 150, 1930).

Curve 3 is based on the Williams-Hazen Tables for average soft unfiltered river water.

Curve 4 is a composite for supply and transmission lines 16 in. or larger in diameter.

Curve 5 is a composite of Curves 4 and 6. Composite curves are based on arithmetic averages.

Curve 6 is a composite for distribution mains less than 16 in. in diameter.

For supply and transmission mains 16 inch and larger in diameter ..... C = 135

For distribution mains less than 16 inch in diameter, with allowance for Ts, valves, bends, corporation cocks, or other specials involving friction loss..... C = 125

Variations possibly approaching 10 per cent higher or lower may be found, but the foregoing represent the average values from data available to the Committee.

The most widely used basis for estimating the probable loss of capacity of tar-coated cast iron pipe with age, (other than the convenient, though inadequate, assumption that C = 100) is the age-coefficient relation shown in the column headings of the Williams-Hazen tables.

These Williams-Hazen predicted age coefficient relations—or trends of C—accordingly form a convenient basis for comparison with actual trends computed from the data submitted to the Committee.

The data compiled on actual trends of the age-coefficient relation for tar-coated C. I. pipe includes a total of 473 tests in 19 different cities. These data, results of which have not heretofore been published, have been classified and are presented in the form of trend curves.

These trend curves, as in the assumption of values for new pipe, have been segregated into two major classifications, namely, for supply and transmission mains 16-inch and over in diameter, and for distribution mains less than 16-inch in diameter.

Further classification has been made by grouping trend curves of similar type or source of supply; or according to general location or type of supply.

Summary of Data on Actual Capacity Loss in Tar-Coated C. I. Pipe

The data on actual loss of capacity in tar-coated C. I. mains may be briefly summarized, as follows:

Supply lines in nine cities showed a loss after 30 years of 37 per cent as compared with a predicted Williams-Hazen loss of 30.8 per cent.

Distribution mains in ten cities showed an actual loss in 30 years of 64 per cent as compared with a Williams-Hazen predicted loss of only 37 per cent.

Average results of 473 tests in 19 individual systems, including sizes ranging generally from 6-inch to 48-inch in diameter with a weighted average size (according to numbers of tests of each size) of 20.5 inches, showed an actual loss in 30 years of 51.5 per cent, as compared with a predicted loss of 32.3 per cent for pipe of the same diameter.

These data accordingly indicate that the Williams-Hazen predicted trends are applicable primarily to large diameter mains carrying relatively inactive water—and do not represent "average conditions."

Quality of Supply and Its Effect on Capacity Loss

The wide variation in rate of capacity loss in different systems and the appreciable extent to which this loss progresses in a relatively short time in many systems, directs attention to probable causes of such loss. In collecting data, the Committee has accordingly attempted to consider the quality of supply and its effect upon rate of capacity loss.

Alkalinity and carbon dioxide have an important effect on rate of capacity loss. Because of the inter-relation between alkalinity, carbon dioxide, and pH, this effect may be measured against the pH value alone.

The relation of pH to rate of capacity loss has been illustrated in the report by a diagram on which the per cent of capacity loss in a fixed period, (30 years) in various supplies, has been plotted directly against the pH of the supply.

The pronounced relation indicated by the data, showing the marked effect of pH on the relative rate of loss, may be summarized as follows:

pH Value of Supply	Approximate Average Per Cent Capacity Loss in Tar-Coated C. I. Pipe (In 30 Years)
8.0	30
7.5	35
7.0	45
6.5	60
6.0	85

Capacity Loss in Tar-Coated C. I. Pipe Due to Special Causes Other Than Tuberculation

Although tuberculation is most frequently the cause of loss of capacity in tar-coated cast iron mains, certain cases included in the Committee data afford examples of capacity loss due to other special causes. In some instances the resulting trends of capacity loss are quite similar to cases where loss was caused by tuberculation. Among special causes of capacity loss are: incrustation, due to the precipitation on the pipe either of natural mineral content in the water, or of lime after water treatment; slime or fungus growth; and silting.

Coefficient Values of Cement-Lined Pipe

In addition to the main section of the report dealing with friction coefficients of tar-coated cast iron pipe, a number of related subjects involved in the general question of friction coefficients, are discussed.

Accordingly a second section of the report is devoted to coefficient values of cement-lined pipe.

The development of the centrifugal method of applying cement lining has inevitably resulted in the increased use of this type of lining as a method of preventing capacity loss. Available data upon the values of C for cement-lined pipe are limited in scope and widely scattered in the literature. Accordingly, all available data have been compiled and presented in order that they may be made more readily available.

The Committee data indicates that the average value of C for new pipe, 4-inch to 24-inch in diameter with cement lining centrifugally applied, is 134, based on nominal diameter; and 150 based on actual net diameter.

These data also indicate that at least for mains 24-inch or less in diameter, the effect of lining thickness on diameter encroachment is sufficient to warrant considering values of C based both on nominal and on actual net diameter.

Other tests on pipe with cement lining not applied by centrifugal methods showed the following values: For pipe with natural or Rosendale cement lining tested both when new and at the end of approximately a 10-year period, C = 136; for old style cement lined wrought-iron pipe 12-inch and 14-inch diameter, after 41 years of service, C = 104.

Available data relative to the value of cement lining in maintaining hydraulic capacity are extremely limited in scope. One line tested when new and again after six years of service showed no loss of capacity. Another line tested when new and after 1, 7, and 10 years of service, also showed no tendency to decrease in carrying capacity with age. The data indicate that cement lining can be credited with a sustained capacity not attainable with tar-coating.

Coefficient Values of Pipe with Bitumastic Enamel Lining Centrifugally Applied

A third section of the report is devoted to a discussion of coefficient values with Bitumastic enamel lining applied by the centrifugal method. As in the case of cement lining, development of centrifugal methods of application have resulted in a greatly increased use of this type of lining to control capacity loss. Due to limited data available, results of all of the tests which have been conducted, together with a discussion of test methods, have been presented in the report. Results available include tests on 10, 12, and 20-inch cast iron pipe; and on 30-inch steel pipe.

The data indicate that coefficient values for new supply and transmission mains 16-inch in diameter and larger, with bitumastic enamel lining (centrifugally applied) may vary from C = 145 to C = 160 with an average value of C = 155; all based on nominal diameter.

These data also indicate that coefficient values for distribution mains less than 16-inch in diameter, with this style of lining, may vary from C = 140 to C = 150 with an average value of C = 145.

Bitumastic enamel lining is ordinarily applied with a thickness of only 3/32-inch. Encroachment on diameter is accordingly small, as compared with other types of lining.

The first application of this type of lining was in 1931, and accordingly no data is available relative to its effectiveness in sustaining hydraulic capacity. The longest service period reported is two years, and the results of this test indicate no loss. The same material applied by the hand-brush method has been widely used for many years, and visual inspection of large pipe thus lined indicates that at least within periods of 16 years no apparent deterioration has occurred.

Application of Linings to Mains in Place

While the foregoing methods of lining pipe provide methods of preventing or retarding capacity loss on new work, the question of restoration of capacity of many miles of mains already in place is of no less importance. The high cost of abandonment and duplication of existing mains, particularly under permanent pavements has directed attention to possible

methods of reconditioning or lining existing mains in place, subsequent to cleaning.

Reference is made in one section of the report to available methods of lining mains in place.

Two methods have been devised in England for lining small diameter mains; the "Eric" process by which a bitumen lining is deposited electrically; and the Tate process, by which a cement-mortar lining is deposited in the pipe.

In this country, two methods have been developed for the reconditioning and lining of large diameter mains. On pipe lines sufficiently large to permit entry, the lines may be carefully cleaned and then treated with an application of hot bitumastic lining. A second method, which has recently been developed, involves the centrifugal application of a cement lining to large diameter mains in place. The lining is whirled into place by centrifugal force from a high speed centrifugal jet.

Corrective Treatment

In addition to the use of protective linings, chemical treatment of the water for reduction of corrosion has been adopted in recent years to abate the problem of capacity loss, and mention is made in the report, of some of the more important phases of corrective treatment.

Lime, sodium hydroxide and soda ash are among the alkalies used to reduce corrosion.

If water is maintained saturated with respect to calcium carbonate, it will be practically non-corrosive to iron.

In maintaining adequate corrective treatment it is essential to maintain the treated water at or very near the saturation point, for super-saturation results in excessive deposits, and under-saturation causes the destruction of the needed protective film.

In corrective treatment, consideration must be given to the fact that the pH value at which saturation equilibrium occurs, varies with the characteristics of the water treated.

The calcium bi-carbonate, (alkalinity) of the water and its magnesium content are the most important factors. Saturation occurs at a pH of only 7.2 with an alkalinity of 190 ppm., whereas with water containing only 15 ppm. alkalinity, the pH must be raised to 9.3.

Accordingly, in planning corrective treatment, particular attention must be given to the characteristics of the water. The fact that a pH of 8.0 for example, is successful in controlling corrosion in one system, is no criterion as to the pH that must be maintained with another supply.

Restoration of Capacity of Unlined Cast Iron Mains by Cleaning

Cleaning of cast iron mains to restore capacity is an important consideration in the problem of capacity loss.

Two important phases of this question are discussed in the report: First, the immediate increase in coefficient values and consequent increase in capacity obtainable by cleaning. Second, the rate of capacity loss subsequent to cleaning, or otherwise expressed, the maintenance of capacity after cleaning.

Data available to the Committee indicate that cleaning will ordinarily retsore mains to approximately 85 per cent of their original capacity. The average value of C in 24 tests was 39 before cleaning, and 104 after cleaning. If it is assumed that the value of C for new pipe was 125, the percentage of original capacity was accordingly 31 per cent before, and 83 per cent after cleaning.

The period through which the relatively high capacity obtained immediately after cleaning is sustained, is subject to wide variations in individual cases. Some instances, particularly with small mains, are recorded, wherein the results of cleaning do not last more than four or five months. In other instances the capacity is maintained at reasonably high values for substantial periods of time.

Summary of Appendices

All of the foregoing subjects deal directly with coefficients with tar-coated cast iron pipe, with the effect of age on coefficient values, or with alternate methods of retarding or preventing capacity loss.

Certain other subjects, while not directly concerned with these questions are, nevertheless, involved in the general questions of pipe-line friction coefficients. Among these related subjects are coefficient values of steel and of concrete pipe.

Coefficient Values of Steel Pipe

A discussion of coefficient values for steel pipe, due to the wide difference in interior surface with various methods of pipe construction, necessitates a definition of the several classes of steel pipe.

The classification of alternate types by Scobey in Bulletin 150 of the U. S. Dept. of Agriculture, provides a convenient standard for summarizing the values of C for various types of steel pipe when new.

The ordinary average values of Williams-Hazen C for various classes of new steel pipe may be summarized as follows:

Corrugated pipe	60
Spiral riveted flow against laps	100
Spiral riveted flow with laps	110
Full riveted	115
Girth riveted	130
Continuous interior pipe	139

Coefficient Values of Concrete Pipe

Available data on concrete pipe indicate an extremely wide range in values of C, with instances of values as low as C = 85 and as high as C = 152. This wide range may be attributed not only to variation in surface texture or roughness of the pipe, but also to the relative uniformity of the pipe bore or, in other words, the presence or absence of undulations on the interior surface.

With these wide variations, particular care must be exercised in selecting values of C for concrete pipe.

Data available to the Committee indicate that the average value of C for the best grade, new, and large diameter precast reinforced concrete pipe, carefully manufactured, may be assumed to approximate C = 150. On the other hand unless rigid metal forms, rich mix of concrete, careful curing and best workmanship throughout are employed, considerably lower values must be anticipated.

Values of C for concrete pipe of different classes and different methods of manufacture are presented in the report, these values being taken largely from a comprehensive paper by Fred C. Scobey, on this subject.

Tests on concrete pipe after substantial periods of service indicate that under normal conditions the initial capacity is relatively permanent.

Summary

The vast financial loss resulting from rapid capacity reduction of pipe systems indicated by the data upon which the report is based, is a matter of major importance to the water works industry. It is believed of sufficient moment to warrant the determination, in each system, of the rate and cause of loss; as a basis for the adoption of the best preventive measures whether they are provision of permanent linings or corrective treatment of the supply.

Upon the basis of the average data on tar-coated cast iron pipe, it is found that in 19 cities the average value of C after 30 years' service was 64, as compared with a value of 88 predicted in the Williams-Hazen tables. Otherwise expressed the value of C dropped to 88 after only 11 years of service instead of after a predicted period of 30 years.

Furthermore, these average figures involve relatively large mains (20.5 inches average diameter). In 8 out of 10 systems the value of C for distribution mains after 30 years' service was less than 50—involving a consequent loss of capacity of from 61.6 to 84 per cent, as compared with a predicted loss of 37.5 per cent.

The trend curves presented in the report, illustrate a wide range of loss of capacity in various systems, and the very considerable magnitude to which such loss develops within a comparatively short period in relation to the structural life of the pipe. It is hoped that these curves will serve to interest members of this and other associations in conducting and recording tests, in order that more selective numerical data may be ultimately made available to the profession.

Elson T. Killam, Chairman; Frank A. Barbour, W. W. Brush, Laurence C. Hough, Charles W. Sherman.

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Manufacturers of

Steel Couplings, Style 38—for plain-end steel, wrought-iron, cast-iron, spiral-welded, concrete, and other fabricated pipe, all sizes.

Cast Couplings, Style 53—for plain-end cast-iron pipe, A. W. W. A. classes A, B, C and D in sizes 3″ to 30″ inclusive.

Mechanical Joints, Style 85—for simpler, faster, easier joining of bell-and-spigot pipe designed to accommodate Bellmaster Joints, in sizes 4″, 6″, 8″, 10″, 12″, and 16″.

Bell-Joint Clamps, Style 60—for making repairs on all sizes of bell-and-spigot joints.

Split Repair Sleeves, Style 26 and Style 57—for repairing (by enclosing) breaks in the bell and on the straight sections of cast-iron pipe.

Split Repair Sleeves, Style 52A and Style 54A—for repairing (by enclosing) various types of joints on steel lines.

The Dresser products most frequently used in connection with steel and cast-iron water lines are shown on this page. Complete information on any Dresser products will be sent upon request. Dresser engineers will be glad to help you solve your joint problems.

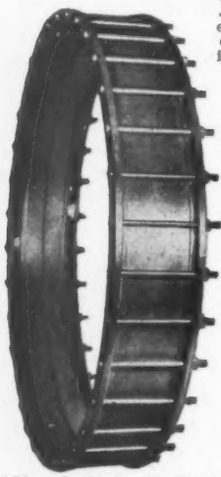
DRESSER COUPLINGS, STYLE 38

(Above)—Style 38 Steel Coupling (12″ ID). Joins plain-end steel (and cast-iron) pipe.

Purpose—The Dresser Coupling is a "factory-made" pipe joint, which (when simply *assembled* on plain-end pipe) makes a *flexible*, permanently tight connection.

Description — Each standard Style 38 Steel Coupling is made up of one middle ring, two followers, two *resilient* rubber gaskets, and a number of bolts (see cross-section below).

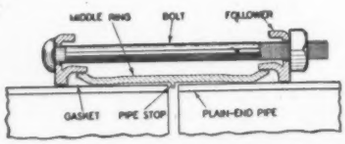
Advantages of the Dresser Coupling Are — (1) *Permanent Tightness*—confirmed by *millions* of field installations. (2) *Flexibility*—for absorbing pipe movements, expansion, settling, curves, etc. (3) *Simplicity*—unskilled labor, using only a wrench, can quickly install — or disconnect. (4) *Strength*—ample to hold safely any specified working pressure. (5) *Economy*—the only joint that insures *true* economy throughout its life.



(Above) Style 38 Steel Coupling (60″ ID) for joining plain-end, large-diameter pipe above 24″.

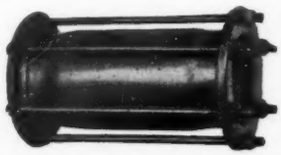
Sizes Available—Style 38 Couplings are made for all standard and special sizes, as well as all kinds of *plain-end* pipe. Size range: ⅝″ to largest pipe made.

How to Order—When ordering, or asking for quotations on Style 38 Couplings, state: (1) quantity; (2) style number; (3) nominal size and outside diameter of pipe; (4) kind of pipe (steel, cast-iron, etc.); (5) working pressure; and (6) service (water, air, sludge, etc.).



(Above) Longitudinal section through a Style 38 Coupling (of typical size).

(Above) Style 38 Steel Coupling (5⅝″ Cas.) for joining plain-end, light-wall steel pipe.



(Above) Style 40 Long Sleeve (6″ ID). Is like Style 38 except has longer body to span variations in space between pipe ends.

DRESSER COUPLINGS, STYLE 53

(Right) Style 53 Cast Coupling (12″ CIP). For use with plain-end, cast-iron pipe under corrosive conditions. Similar to Style 38, except of cast material. Sizes available: 2″ to 30″ incl. (An alternate for these and larger sizes is Style 38 Steel Coupling for cast-iron pipe.) Standard steel bolts, either galvanized or cadmium-plated, are regularly supplied with Style 53—though cast bolts can also be furnished.

DRESSER BELLMASTER JOINTS, STYLE 85

The new Dresser Bellmaster Joint is a single-gasketed, self-contained mechanical joint designed for strength, flexibility, and resistance to corrosion. It consists of an inner ring, rubber-compound gasket, outer ring, and a set of capscrews—all factory-assembled into a single unit. The Bellmaster is installed by inserting it in the bell end of pipe prepared to accommodate the Joint, locking it in place by twisting it slightly clockwise, "stabbing in" the spigot end, and tightening the capscrews. Working principle is simple and effective: as the capscrews are tightened, the inner ring is drawn closer to the locked outer ring, thus expanding the gasket against the outside of the spigot and against the inside of the bell, making a tight seal against both. The Bellmaster is currently available in the following cast-iron pipe sizes: 4-, 6-, 8-, 10-, 12-, and 16-inch; leading cast-iron pipe manufacturers can furnish pipe with bell ends suitable for Bellmaster Joints. Write for illustrated catalog (Form 413A) which lists features and advantages, shows laboratory tests and field views, and contains information on how to order.

DRESSER NO-THREAD FITTINGS, STYLE 65

Convenient, self-contained pipe joint. In standard sizes, ⅜″ to 2″ ID, including Couplings, Ells, and Tees. Comes completely assembled and is installed in a few seconds with but one tool—a wrench. Makes a tight, flexible connection on plain-end pipe. No pipe threading needed.

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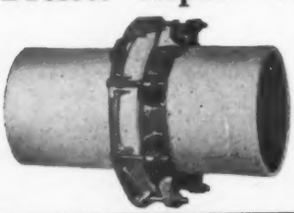
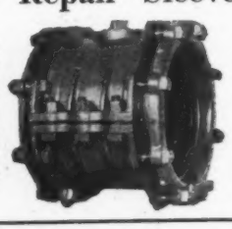
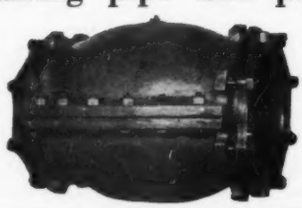


Style 60 Bell-Joint Clamp (12″ CIP). Repairs and prevents leaks in bell joints. Readily adjusted to variations in bell and spigot diameters.



Style 57 Cast Split Sleeve (12″ CIP). Encloses and permanently repairs splits and holes up to 8″ long in straight run of pipe.



Style 26 Cast Split Sleeve (12″ CIP). Encloses and permanently repairs broken or split bell joints.

Write for Bulletins 402B and 413A. Full information sent on request.

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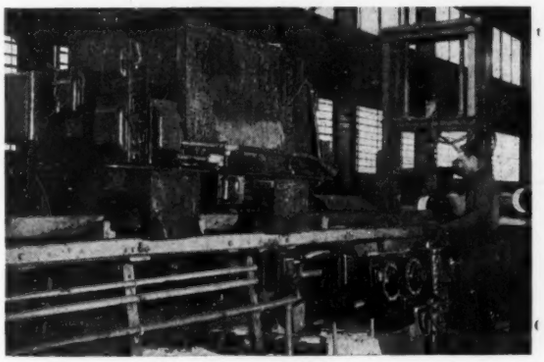
The HILL-HUBBELL "factory process" of applying linings to the more widely used sizes of STEEL PIPE makes it possible for the smaller community, also, to have the many advantages of STEEL PIPE. We line STEEL PIPE from 4½" O.D. to 30" O.D., and coat-and-wrap STEEL PIPE from ¾" Nom. to 30" O.D. Eminent engineers maintain that STEEL PIPE, when Lined inside and Coated-and-Wrapped outside by the HILL-HUBBELL "factory process," is far more practicable than any other type of pipe.

For ECONOMY and SAFETY—USE STEEL PIPE.



Lining STEEL PIPE

BITURINE AKWALINE Lining in any ferrous pipe prevents tuberculation, corrosion, incrustation, and silting—all of which reduce the original carrying capacity of the pipe. An article on "The Prevention of Corrosion of Pipe" (The American Water Works Association, Volume 16, No. 2, 1936) illustrates the practicability of coal tar lining. Two sections of 6-inch pipe were taken from the Brooklyn System in 1925. One section, laid in 1857, had only one-fifth its original carrying capacity. The other section, laid in 1863, with a coal tar lining, still had, after 62 years of service, its ORIGINAL CARRYING CAPACITY.

In the Hill-Hubbell method, the coal tar enamels are applied, mechanically, in a true multiple coat process. Centrifugal force of the revolving pipe evenly disperses the flow of molten enamel from a slowly withdrawn feed line. The result is a lining of guaranteed minimum thickness and of maximum uniformity. The surface of the lining is as smooth as glass and increases the pipe carrying capacity from 7 to 15% and thereby reduces FOREVER, pumping and operating costs.

Our entire lining application is done AT THE PIPE MILLS, INDOORS. No weather hazards affect the quality of our work. With the most highly developed equipment in the industry to properly handle the coating materials, a Hill-Hubbell job of coal tar enamel lining can not be excelled.

More than 12,000 miles of Steel Pipe have been protected against exterior corrosion by the Hill-Hubbell "factory process," establishing the unquestioned leadership and acceptance of our method. All our work is done, right in the steel pipe mills, mechanically, indoors—away from all weather hazards.

Proper handling of the coating materials is assured, for we use heating kettles of our own design equipped with positive thermostatic control and tireless mechanical agitation.

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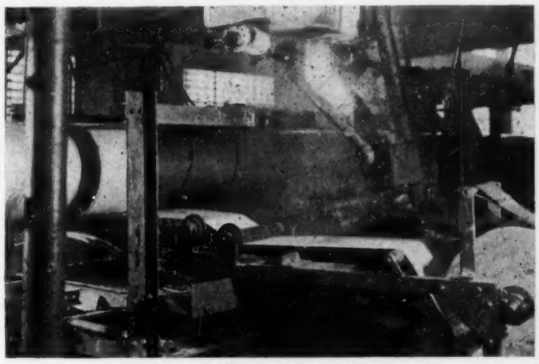
Mill Coating-and-Wrapping is the modern, proven method of pipe protection.



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BITURINE AKWALINE Enamel is an all-coal tar pitch enamel developed especially for lining water mains and supply lines. It meets the accepted sagging test at 160° F. and the usual cracking test at —10° F. When your STEEL PIPE is lined with BITURINE AKWALINE Enamel by the HILL-HUBBELL "factory process," it can not be excelled because the RIGHT enamel is PROPERLY applied. No matter how good the lining is, it must be PROPERLY applied to give 100% protection.

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BITURINE Enamel is used for coating STEEL PIPE outside. It is an all-coal tar pitch enamel and has been doing an efficient protection job for over 30 years. BITURINE Enamel, with the additional reinforcement of shielding wrapper, PROPERLY applied at Mills, is now protecting thousands of miles of STEEL PIPE in all parts of the country.

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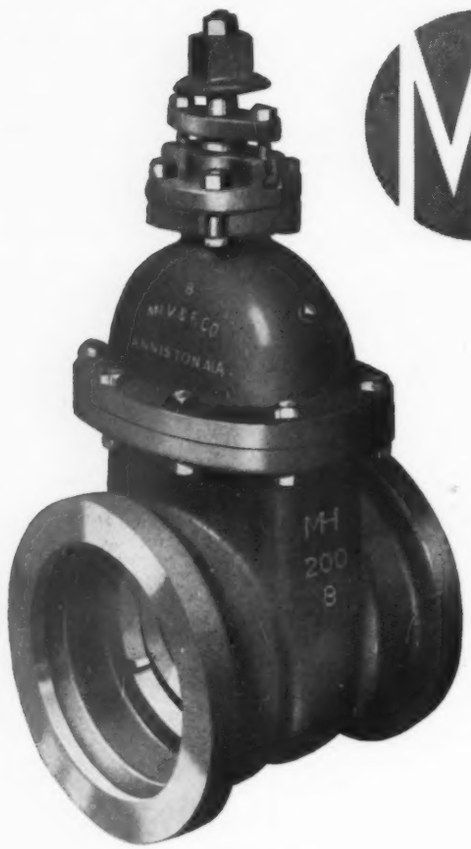
VALVES, HYDRANTS AND WATER WORKS ACCESSORIES

Protection of municipal water systems and municipalities themselves under the U. S. National Defense Program involves a greatly increased number of control valves and hydrants on the water mains. M & H products with their record of high quality, rugged strength and dependability can safely be recommended.



M & H FIRE HYDRANTS

Conform to latest A.W.W.A. specifications. Simple rugged design minimizes maintenance costs. Features are:

1. **Dry Top—Operating threads protected from action of water. No rust, corrosion or freezing.**
2. **Easy Lubrication of operating nut, threads and packing through lubricating screw in top of operating nut.**
3. **Revolving Head, outlets faced in any direction.**
4. **Addition of Steamer Nozzle, without digging up hydrant or requiring complete new barrel.**
5. **Lengthening of Hydrant without digging up or requiring complete new barrel.**
6. **Double Lead Gaskets on Bronze valve seat.**
7. **Removal of Bronze Seat, or any working part, without digging up Hydrant.**
8. **Double Drain Valves, absolutely positive, insuring quick and complete draining of Hydrant.**
9. **Lugs on Bell of Hydrant Shoe for strapping to the water main, if desired.**
10. **Compression Type. Water pressure keeps valve tight.**

SPECIAL TRAFFIC MODEL FIRE HYDRANT

Equipped with cast iron bolts and breakable coupling on the stem. Breakage due to traffic collision is limited to these cast iron parts which are easily and quickly replaced without shutting off the pressure.

M & H A.W.W.A. GATE VALVES

Iron body, bronze mounted gate valves are furnished in the double disc parallel seat or solid wedge types with non-rising stem, outside screw and yoke, or with sliding stem and lever. Supplied to fit any standardized pipe connections. By-pass valves can be furnished, unless otherwise specified, in sizes according to A.W.W.A. specifications.

SPECIAL TYPES

Hydraulically Operated: **for remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.**

M & H Square Bottom Gate Valves: **specially designed for operation in any position. Particularly recommended for use in intake towers or at the foot of dams; for pressure regulation by throttling the flow of water in centrifugal pump discharge lines; for regulation of flow in feed line to a filter bed; and for flow regulation from a reservoir where there is unbalanced pressure against the gates.**

PRESSURE CLASSIFICATION—2″ TO 30″ SIZES

Class	Working Pressure	Hydrostatic Test
AA	0 - 25 lb.	50 lb.
A	26 - 50 lb.	100 lb.
B	51 - 100 lb.	200 lb.
C	101 - 200 lb.	350 lb.

CHECK VALVES

For installation in horizontal or vertical position. Can be supplied with by-passes. May be furnished with outside lever and weight. Sizes from 2″ to 12″ for working pressures up to 200 lbs.

OTHER PRODUCTS

Tapping Valves
Mud Valves
Shear Gates
Flap Valves
Wall Castings
Floor Stands
Flanged Fittings
Flange and Flare Fittings
B & S Fittings
Cutting-In Tees
Valve Boxes
Special Castings

HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

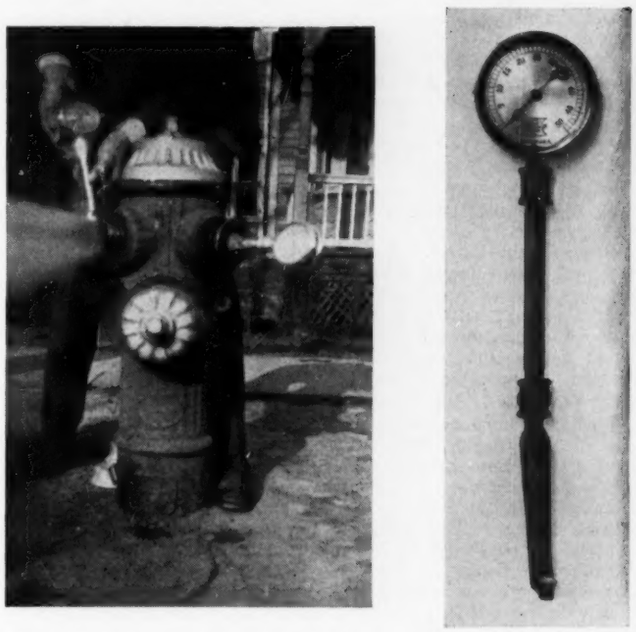
By P. S. WILSON

Water Works Consultant, Glen Ridge, N. J.

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can authorize for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.



Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings) Hydrant Pitot Tube with Gage at Right

Methods of Measuring Hydrant Discharge

Measurements of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle used should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center will be found to be practically the average. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained a diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

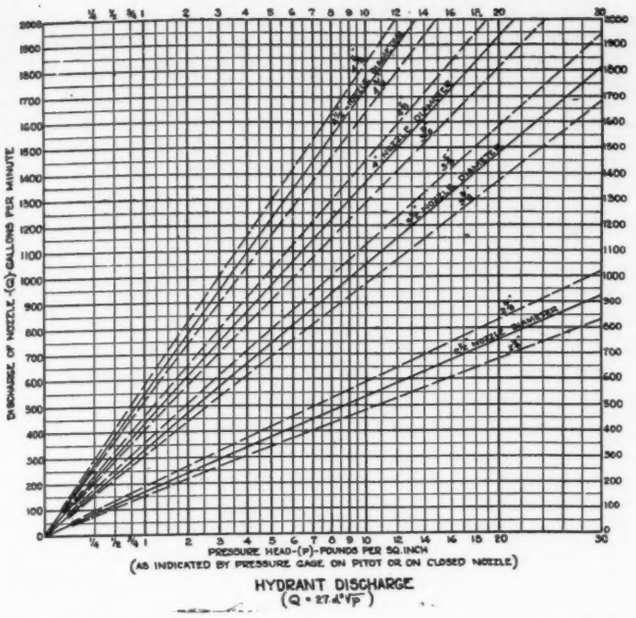
From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

TABLE 1—HYDRANT DISCHARGE*
Gallons per minute = $27 d^2 \sqrt{p}$

Gage Reading—Hoze nozzle diameter in inches [d]						
p	2⅛	2⅜	2⅝	2½	2⅞	2⅝
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.


DISCHARGE OF NOZZLE-(Q) GALLONS PER MINUTE
PRESSURE HEAD-(P)-POUNDS PER SQ. INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4 d² √P)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary. Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280$$ gal. per min. which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1, is the measured discharge with a drop in pressure of D_1: and, Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association*, Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

[*See also "Pipe Flow Diagram" and "Flow Powergraph" which appear in Part III.*]

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 ½-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1 ½-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

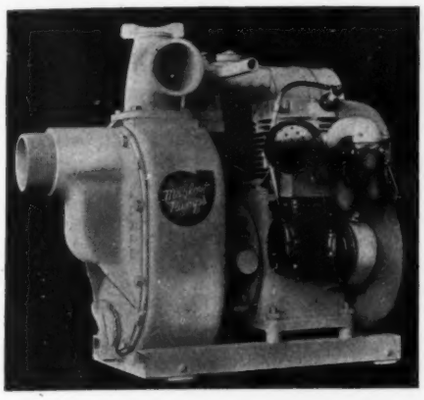
NORTHROP & COMPANY, INC.

Water Works Specialties and Supplies

50 Church Street • **NEW YORK, N. Y.**

MARLOW Lightweight, Self-Priming Centrifugal Pumps

3,000, 7,000 and 12,000 G.P.H.

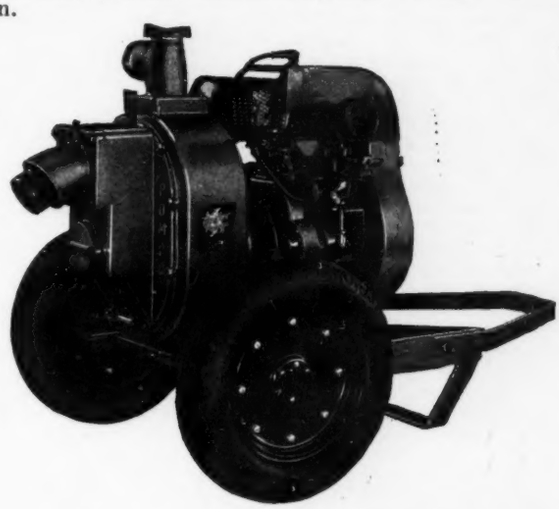


1½", 2", and 3" sizes weighing respectively only 60*, 100, and 106 lbs. (*76 lbs. with cast iron pump). Easily carried by one or two men. 25 foot vertical suction lift and will discharge against a total head of 55 ft. Powered by four cycle, air-cooled gasoline engines equipped with magneto ignition, speed changer and tapered roller bearings on crankshaft.

The pump shell is self-cleaning with open type impeller specially adapted for dirty water. A special long-wearing shaft seal replaces packing. Aluminum alloy construction.

FREE TRIAL

Two weeks' trial of any Marlow Light-Weight with full credit return if not satisfactory.



Two Wheel Mounted—7,000 to 200,000 G.P.H.

2" to 10" Marlow gasoline engine powered units are mounted upon pneumatic or steel tired trailer carts.

Pumps are equipped with trash type impellers, self-cleaning casings and special long-wearing shaft seals. Special feature allows removal of trash accumulated in the suction housing through hand hole plate without stopping engine or losing priming water. Automatic control device prevents re-circulation of water after pump is primed.

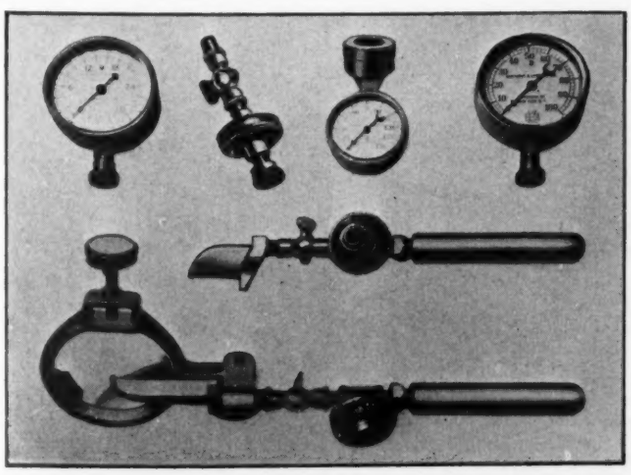
Also complete line of Marlow Diaphragm and Plunger pumps.

NORTHROP Water Works Test Sets

A complete test set for hydrant flows, pressure and loss of head. This set contains two Pitots with gauges, a faucet gauge which can also be used as a hydrant pressure gauge, and a hydrant adapter for use with the faucet gauge. All parts are chromium finished.

The gauges are manufactured to specifications furnished by the National Board of Underwriters. One gauge indicates both pounds pressure and approximate equivalent in gals. per min. when used on 2½" hydrant connections.

The Hand Pitot or Combination Hand & Clamp Pitot, each with a 2-scale gauge, may be ordered separately. These sets as well as the complete set are shipped in handsome carrying cases. Instructions for making Hydrant Discharge Measurements are enclosed.



A—Hand Pitot with Air-Chamber and Throttling Cock.

B—Combination Hand and Clamp Pitot with Air-Chamber and Throttling Cock.

C—Two-Scale Gauge for 2½" hydrant openings; lbs. pressure and gals. per min.

D—Hydrant Cap Gauge —100 or 150 lbs.

E—Faucet Gauge—100 or 150 lbs.

F—Hydrant Cap Adapter.

G—Carrying Case.

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ELECTRICAL THAWING

of Service Lines and Small Mains

By FRANK C. AMSBARY, Jr.
Superintendent
Champaign, Illinois

THE following review of factors entering into the problem of thawing water service pipes is based upon the use of electrical energy derived either from transformers connected to convenient power lines, or the gasoline engine driven welders. These comments, suggestions and recommendations, being presented at the request of the editor of "Water Works and Sewerage," are based on long experience by the writer's company with electrical thawing methods.

Selecting a Transformer

In the selection of a transformer for this purpose, two classes of equipment are available. The small portable transformer which is connected to the house electrical service lines and transformers which must be connected to the power company lines on the poles.

The small portable transformers with which we have had experience, due to the limited current carrying capacity of the electric service into the average residence, necessarily has a small output, resulting in limited applications and slow thawing. However, it is particularly suitable for thawing plumbing inside of structures or where only a short run of small pipe has been frozen, also for services of lead.

For all purpose use the transformer connected directly to the lines on the power company poles is usually the best. If this source of energy is chosen, suitable arrangements for the transformer, a lineman to make the primary connections, and a satisfactory energy charge can undoubtedly be made through the local office of the power company.

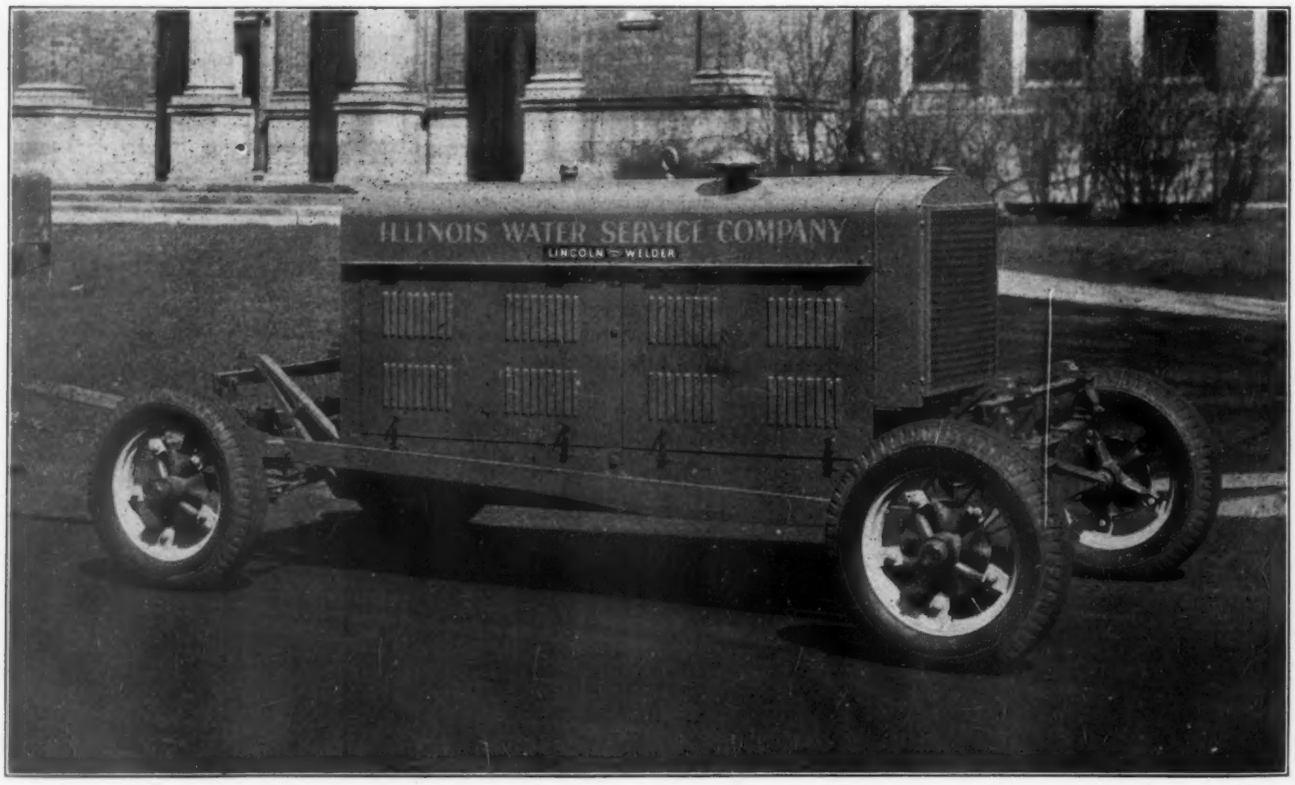
The power company should be cautioned to furnish a transformer with the *lowest voltage available on the secondary* to keep handling hazards at a minimum, and a current capacity of not over 200 amperes if the services to be thawed are of steel, wrought iron, lead, or cast iron, and not over 400 amperes if the services are of copper.

Welding Generator Units

The gasoline engine driven welder is probably the most flexible unit available for thawing purposes. Being an entirely self contained unit, it is not dependent upon the necessity of an adjacent power line, and any intelligent employe can readily operate it. No lineman is required.

A Unit of Ottawa's Thawing Fleet

In the selection of a welder, it is suggested that the voltage be somewhere between the limits of 30 and 60, and if no copper pipe is used in the distribution system, the amperage be limited



Our Combination Welder and Thawing Unit
Purchased for Thawing, and Use Also as a Welder, This Heavy Duty Unit Has an Output Range of 150 *to* 600 *Amperes at* 40 *Volts.*

to 200 amperes. If copper pipe is likely to be encountered, the upper limit should be 400 amperes.

There is a considerable difference between the cost of a 200 ampere and a 400 ampere welder, and this difference in cost cannot be justified if there is no need of the larger currents.

All welders are equipped with controls to regulate the amperage, which readily adapts even the 400 ampere welder to any of the service materials in common use.

Suggesting Current Rate for Various Materials

The following table showing the resistance and approximate melting points of the more common metals used in service lines, along with the suggested rate of current to be used for each, tells a comprehensive story of thawing in itself.

It is suggested that operators of the thawing equipment be furnished copies of this table to carry with them at all times, so each will be fully advised of the conditions that must meet on each job, by ready reference.

Metal	Ohms Per Milfoot*	Approximate Melting Point	Suggested Rate of Current
Copper	9.35	1900° F.	300 to 400 amps
Steel	63.00	2600° F.	200 amps
Wrought iron ..	82.80	2800(F.	200 amps
Lead	123.00	625° F.	75 to 150 amps
Cast iron	684.00	2500° F.	75 to 150 amps

*Resistance in piece of metal which is .001 inch in diameter and 1 foot long.

The smaller the value in ohms per milfoot, the higher the rate of current required to produce sufficient heat to melt the ice. For this reason the highest rates are recommended for copper. Due to the high resistance of lead and cast iron, lesser rates will accomplish the desired results in a reasonable time and *in all cases the smallest rates compatible with time* should be used to eliminate dangers always present when large currents are used.

The melting point of the metal of the more generally used materials found in service construction is included in the above table to suggest the danger of melting lead service pipes. It will be noted that lead, which has the lowest melting point, also ranks next to the highest in resistance. To prevent over-heating and melting of lead, the low rates must be used. It follows that the 75 to 150 amperes which is recommended for lead will thaw a service of this material in a reasonable period of time, while if this same rate is used on copper, due to its low resistance, the heat generated will be negligible.

Rates recommended for lead should be used where lead goosenecks are used regardless of the material used in the balance of the service. Lead joints in cast iron pipe must likewise be protected by the use of small rates.

Time Required Depends Upon Current

The period of time required to thaw a service is inversely proportional to the *square* of the current. For example, with a one-half inch service, if it requires 10 minutes to thaw at 200 amperes, it will require 40 minutes at 100 amperes.

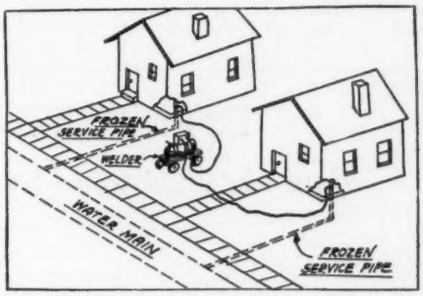
Regardless of the number of services waiting to be thawed, *time should be secondary to safety;* and, for safety, the rates recommended in the table should not be exceeded.

Wire Size Important Also

The following table gives safe current carrying capacity for the leads from the source of energy to the pipe to be thawed. It is assumed that the length of such lead wires will be kept at a minimum.

Size Wire B & S	Safe Current Carrying Capacity*
O	200 amps
OO	225 amps
OOO	275 amps
OOOO	325 amps

*For short periods of thawing twice these rates of flow may be safely employed.

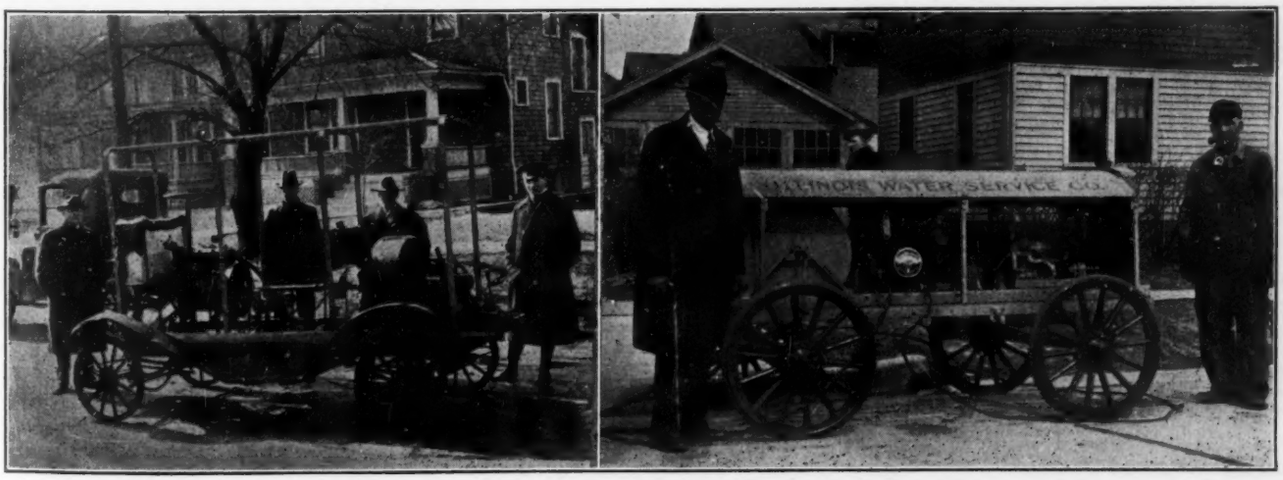


Suggested Thawing Hook-Up
By This Arrangement Two Services Can Be Thawed at One Operation. If Only One Service Is to Be Thawed, One Wire (Either One) May Be Connected to a Fire Plug. Before Turning on the Current It Is Important to Disconnect the House Piping From the Service Lines.

Procedure and Precautions:

The following example for thawing a frozen service is based upon the assumption that meters are set in the basement, and the thawing circuit is closed by connecting one wire from the source of energy to the frozen service pipe in the basement and the other wire to the service pipe in the adjacent house (see sketch); also that a good quality C clamp, or similar appliance for making the electrical contact to the pipe, is used. It is recommended that a solderless lug be clamped on the end of the wire and then securely bolted to the C clamp.

First remove the meter in each basement or in some way break all connection between the house piping and the line to be thawed. Remember that in thawing services one is dealing with a current that in some cases is as high as 40 times the average lighting demand of a home. Due to grounding of house lighting circuits



1918—*Other Equipment We Have Known*—1929
(Both Being Put Together in Our Own Shop)

to water pipes, if the meters are not removed, or some other break made in the line, the current used in thawing the service may feed back into the light circuit and cause serious damage. Houses have been burned down due to such a condition. Another source of feed-back is through the water heater to the gas line, which may melt the lead gaskets in the gas meter.

Special care should be exercised to see that all rust, scale, grease, etc., is removed from the pipe at the point where the C clamp is fastened to the pipe. Unless a good contact is made, arcing is likely, which may cut holes completely through the pipe. Poor connections also waste electrical energy and slow up thawing.

The connections now having been made to both services, thawing may be started. Do not make the common mistake that has caused trouble by assuming the removal of the meters will eliminate all sources of feed-back from the thawing circuit. Water pipes may make contact underground with the gas distribution system and thus feed-back into the house. During the entire period of thawing constant check on the gas pipes in both houses should be made, as well as to adjacent properties that are entirely out of the circuit established for thawing. Lead gaskets in gas meters have been melted out in the basements of homes not included in the thawing circuit. Continually check connections and joints in the circuit to see that they are not overheating.

Some Final "Dos and Don'ts"

(1) Use the smallest current possible to accomplish the job; do not hurry by using large currents.
(2) Be sure of good electrical contact from source of energy.
(3) Be sure your wires from the source of energy are adequate.
(4) Be sure that you know the material used in the service and adjust the current used accordingly.
(5) Be sure to check for any feed back of the current used in thawing through the gas service. Any heat detected by placing the hand on the gas meter couplings will immediately indicate such a condition.

Polarity does not really make much, if any, difference in the efficiency of the circuit.

But—NEVER FORGET THAT IN THE USE OF LARGE CURRENTS IT ALWAYS PAYS TO BE CAUTIOUS!

ESTIMATING THE COST OF MAINS

And the Setting Up of a Useful Estimating Guide Chart

By D. R. TAYLOR
Plant Superintendent
Roanoke Water Department, Roanoke, Virginia

AMONGST the vicissitudes and pleasures of life and the progress of industry and commerce, prognostication continues to be increasingly interesting to most of us. As time goes on, our material and cost estimates, like mathematical formulæ involving infinity, continue to approach something that they may never actually reach—namely, factual perfection.

Even the average life span of such an everyday thing as cast-iron pipe is still a matter of conjecture. Authentic records of the earliest cast-iron pipe still in service include that supplying water to a fountain at Langensalza, Germany, which was laid prior to 1562, and cast-iron pipes are still supplying the fountains of Versailles, France, after 276 years of service. There are many records going back over 150 years in England and more than 100 years in this country. Such records as these have often been the cause of much difference of opinion among engineers in the appraisal of the net worth of water plants.

Estimating the Cost of Mains and Extensions

The accompanying tabulation has been prepared by the writer for use as a handy reference in estimating. It is based on the average cost of mains under an average group of conditions and methods. Considering that each of the sixty-six items, making up the aggregate, vary according to varying conditions and methods, it may be easily appreciated that, any number of combinations of these items may influence the end result in accurate estimating.

Some of the items shown may be performed at a lower cost than indicated, while others may cost more. As a matter of fact, methods and costs will undoubtedly vary between jobs in the same locality; however, the fact remains that an estimate is necessarily based on an average of as many representative jobs as can be reviewed at the moment.

While there are many very reliable records of total costs of mains, it is surprising what little information can be obtained relative to the man hours and equipment hours required to perform the individual items comprising the total job.

Applying Correction Factors

These man and equipment hour units are shown for the more variable items to enable anyone to calculate an estimate of his costs by substituting his prevailing labor and equipment prices in deriving required correction factors. It is, of course, understood that prices of materials will vary between times and places, especially cast-iron pipe, and it is assumed that quotations on these will be obtained in each specific instance, and a correction factor derived for application.

rially less than that of "standard" pipes specified and used in former years.

As times goes on and more records and improved equipment become available, undoubtedly modifications and adjustments will

In the case of cast iron pipe of sizes 30 inches and larger, the manufacturers will send their representatives to inspect the site of the proposed project and design lighter but higher tensile strength pipe to suit the particular conditions such as depth of cover and weight and intensity of traffic. Such pipe now obtainable through modern methods can be furnished at prices matebe suggested. In the meantime, accumulating cost records should be extremely interesting and the accompanying table should serve a useful purpose in arriving at more dependable cost data in water main construction, which will be highly useful in setting up estimates.

Note—This tabulation of estimating data constitutes a material amplification of an earlier tabulation used by Mr. Taylor and reproduced in the 1940 *Reference and Data Number of this magazine. In his successful attempt to better the original tabulations the following excerpts from Taylor's letter are significant.*

"During the last two years I have talked with a great many contractors, engineers and water works operators and have been surprised to learn that none of them knew the unit man and equipment hours required to perform the various items in laying mains.

"During the last year we have been doing some unit accounting in all of our construction and maintenance work in an effort to determine these units, with the idea of making a tabulation with which any operator in any city or town could substitute his labor and equipment costs and calculate an estimate of the cost of mains. In addition to this, I wrote the pipe manufacturers for such information as they might have. Such proved to be practically nothing.

"In discussing the matter and exchanging experiences with others, they said if I succeeded in working out a tabulation of units, that it would be a real contribution.

"Considering this a challenge, I began collecting information from equipment manufacturers, our records, the records of the city street repair department and state W.P.A. records, and slipped a slide rule at night and during week-ends for the last ninety days, and wound up with the enclosed tabulation, which may not be perfect by any means, but at any rate it is a start and the only thing of its kind that I know of in this country."—D.R.T.

ESTIMATE OF COST OF MAINS PER FOOT

		GALVANIZED			CAST IRON											
1	Size of main	1"	1½"	2"	2"	4"	6"	8"	10"	12"	16"	18"	20"	24"	30"	36"
2	Trench-width	18"	18"	18"	20"	20"	20"	22"	24"	26"	30"	34"	36"	41"	46"	52"
3	depth	38"	38"	39"	40"	48"	52"	54"	56"	58"	64"	68"	71"	77"	86"	93"
4	Cover over bells	37"	37"	37"	36"	40"	41"	41"	41"	41"	42"	44"	44"	46"	48"	48"
5	MATERIALS—plus 1% for waste															
6	Pipe (cast iron F.O.B. siding)	.12	.14	.18	.26	.55	.80	1.13	1.52	1.95	2.99	3.60	4.20	5.60	7.83	10.67
7	Add-for cement lining				.02	.04	.07	.10	.13	.17	.19	.23	.26	.35	.40	.55
8	Add-for bituminastic lining				.03	.06	.08	.12	.16	.21	.24	.29	.34	.45	.64	.87
9	Haul pipe—up to one mile											2.34	2.68	3.12	3.75	4.16
10	Crane & operator-hrs. per 100 ft. (one at ea. end of haul)				.184	.430	.750	1.140	1.560	2.040	3.120	2.34	2.68	3.12	3.75	4.16
11	Truck & driver-hrs. per 100 ft. (two of each)				.750	1.700	3.000	4.600	6.300	8.400	12.500	4.68	5.36	6.24	7.50	8.32
12	Man hours per 100 feet											.0702	.0804	.0936	.1125	.1248
13	COST—Crane & operator at $3.00 per hr.				.0014	.0032	.0056	.0086	.0117	.0153	.0234	.0176	.0201	.0234	.0281	.0312
14	—Truck & driver at $0.75 per hr.				.0029	.0065	.0114	.0175	.0240	.0320	.0475	.0178	.0204	.0237	.0285	.0316
15	—Labor at $0.38 per hr.															
16	Add 2% to lines 13, 14, & 15 for each extra mile					.0220	.0330	.0440	.0550	.0660	.0907	.1017	.1155	.1430	.1760	.2090
17	Joint compound at $0.12 per pound					.0017	.0025	.0032	.0037	.0044	.0057	.0064	.0070	.0082	.0200	.0241
18	Braided hemp at $0.20 per pound															
19	PAVEMENT—square yards per linear foot	.1666	.1666	.1666	.1855	.1855	.1855	.2032	.2222	.2400	.2780	.3142	.3332	.3800	.4260	.4830
20	Removal-compressor & two paving breakers															
21	Asphalt 8"—Equipment at 20 sq. yds. & $0.85 per hr.	.0071	.0071	.0071	.0079	.0079	.0079	.0086	.0095	.0102	.0118	.0134	.0142	.0162	.0181	.0205
22	—Labor at 2. 5 sq. yds. & $0.38 per hr.	.0253	.0253	.0253	.0282	.0282	.0282	.0309	.0338	.0365	.0423	.0478	.0507	.0578	.0648	.0735
23	Concrete 8"—Equipment at 5.0 sq. yds. & $0.85 per hr.	.0283	.0283	.0283	.0315	.0315	.0315	.0346	.0378	.0408	.0473	.0535	.0566	.0646	.0724	.0821
24	—Labor at 1.25 sq. yds. & $0.38 per hr.	.0533	.0533	.0533	.0594	.0594	.0594	.0651	.0712	.0767	.0890	.1008	.1066	.1215	.1362	.1542
25	Brick on 6" concrete—Equip. at 4.0 sq. yds. & $0.85 per hr.	.0353	.0353	.0353	.0393	.0393	.0393	.0431	.0472	.0508	.0590	.0667	.0706	.0805	.0902	.1022
26	—Labor at 1.0 sq. yds. & $0.38 per hr.	.0633	.0633	.0633	.0705	.0705	.0705	.0772	.0845	.0912	.1058	.1095	.1268	.1442	.1620	.1835
27	EXCAVATION—cubic yards per linear foot															
28	Entire depth	.1760	.1760	.1810	.2060	.2470	.2680	.3050	.3460	.3880	.4950	.5930	.6600	.8150	1.0200	1.2400
29	Under 8" asphalt or concrete	.1390	.1390	.1440	.1650	.2060	.2270	.2600	.2960	.3350	.4330	.5230	.5860	.7300	.9250	1.1330
30	Under brick on 6" concrete	.1252	.1252	.1302	.1493	.1903	.2113	.2428	.2780	.3146	.4100	.4970	.5580	.6985	.8900	1.0925
31	COST—by hand at .375 cu. yds. & $0.38 per hr.															
32	Line 28—earth	.1782	.1782	.1835	.2087	.2501	.2718	.3090	.3509	.3930	.5020	.6010	.6690	.8260	1.0340	1.2580
33	Line 29—earth	.1410	.1410	.1460	.1672	.2088	.2300	.2635	.3000	.3399	.4380	.5300	.5940	.7400	.9370	1.1500
34	Line 30—earth	.1270	.1270	.1320	.1514	.1930	.2140	.2460	.2820	.3190	.4160	.5040	.5660	.7080	.9020	1.1090
35	Medium soft shale at $2.25 per cubic yard (line 28)	.3960	.3960	.4075	.4640	.5560	.6030	.6860	.7780	.8730	1.1140	1.3340	1.4860	1.8340	2.2940	2.7900
36	COST—by machine, operator, helper, & three laborers at 25															
37	cu. yds. & $7.60 per hr.															
38	Line 28—earth only or earth & asphalt	.0535	.0535	.0550	.0626	.0751	.0815	.0927	.1051	.1180	.1502	.1801	.2008	.2478	.3100	.3770
39	Line 29 & 30 after concrete & brick removed	.0423	.0423	.0437	.0502	.0626	.0690	.0790	.0900	.1019	.1315	.1590	.1780	.2220	.2810	.3444
40	Hard rock-equipment, materials & labor at 0.5 cu. yds. &															
41	$1.60 per hr. (line 28)	.5630	.5630	.5780	.6590	.7900	.8570	.9760	1.1080	1.2410	1.5820	1.8980	2.1100	2.6100	3.2600	3.9680
42	Add for bracing-to lines 32, 33, 34, 33 & 39									.09	.10	.11	.12	.13	.14	.15
43	LAY PIPE—crane & operator-hrs. per 100 feet											2.78	3.46	3.88	4.30	4.68
44	—man hours per 100 feet	5.270	5.270	5.270	5.270	18.40	23.70	26.30	31.60	36.80	44.70	19.50	24.20	27.20	30.10	32.80
45	COST—crane & operator at $3.00 per hr.											.0834	.1038	.1164	.1290	.1408
46	—labor at $0.38 per hr.	.020	.020	.020	.020	.070	.090	.100	.120	.140	.170	.0742	.0920	.1032	.1188	.1245
47	BACKFILL—entire depth—cubic yards per foot	.1584	.1584	.1629	.1854	.2223	.2412	.2745	.3114	.3492	.4340	.5160	.5660	.6800	.8100	.9470
48	COST—by hand at 1.0 cu. yd. & $0.38 per hr.	.0602	.0602	.0618	.0705	.0845	.0916	.1042	.1182	.1328	.1650	.1960	.2150	.2582	.3080	.3220
49	—by machine, operator & four laborers											.0612	.0727	.0798	.0960	.1142	.1335
50	—at 25 cu. yds. & $3.52 per hr.	.0223	.0230	.0229	.0262	.0314	.0340	.0387	.0439	.0493	.2472	.2940	.3228	.3880	.4620	.5400
51	TAMPING—by hand at 0.666 cu. yds. & $0.38 per hr. (line 47)	.0905	.0905	.0928	.1058	.1270	.1375	.1565	.1775	.1990						
52	—by machine—one compressor & five tampers															
53	—equipment at 10 cu. yds. & $0.85 per hr.	.0135	.0135	.0138	.0158	.0189	.0205	.0234	.0264	.0297	.0369	.0438	.0481	.0578	.0688	.0720
54	—labor & 2.0 cu. yds. & $0.38 per hr.	.0301	.0301	.0309	.0352	.0423	.0458	.0522	.0592	.0664	.0825	.0980	.1075	.1292	.1540	.1800
55	SURPLUS—cubic yards per linear foot	.0176	.0176	.0181	.0206	.0247	.0268	.0305	.0346	.0388	.0610	.0770	.0940	.1350	.2100	.2930
56	COST of disposal at $0.75 per cu. yd.	.0132	.0132	.0136	.0155	.0186	.0206	.0229	.0260	.0291	.0457	.0577	.0705	.1012	.1575	.2200
57	PAVEMENT—cost of restoration (line 19)															
58	Asphalt 8"—at $1.25 per sq. yd.	.2082	.2082	.2082	.2320	.2320	.2320	.2540	.2780	.3000	.3480	.3930	.4170	.4750	.5320	.6040
59	Concrete 8"—at $4.00 per sq. yd.	.6660	.6660	.6660	.7420	.7420	.7420	.8130	.8900	.9600	.1112	.1260	.1332	.1520	.1702	.1930
60	Brick on 6" concrete—at $5.00 per sq. yd.	.8330	.8330	.8330	.9270	.9270	.9270	1.0150	1.1120	1.2000	1.3900	1.5720	1.6660	1.9000	2.1300	2.4100
61	COST of connection at intersection (see line 64)	.65	1.00	1.50	3.00	10.00	14.00	20.00	27.00	34.00	47.00	57.00	68.00	95.00	158.00	268.00
62	COST of valves with small boxes (see line 64)	6.50	9.00	12.50	12.50	18.00	27.00	39.00	61.00	78.00						
63	COST of valves vaulted with brick (see line 64)					30.00	39.00	55.00	78.00	97.00	270.00	350.00	427.00	593.00	918.00	1390.00
64	Multiply number of each by unit cost and divide by length in feet for cost per foot															
65	Treat specials as in line 64															
66	Add 10% for supervision and small tools—5% for work in intermediate sections & 10% for congested sections															

These tabulations do not include fire hydrants, office overheads, engineering, fixed charges, insurance, first aid, etc. Units and costs are based on using workers and laborers experienced in water works construction. For inexperienced workers and common labor the units will be somewhat lower and costs per foot somewhat higher. Units and costs are also based on best conditions in outlying partially built up sections. For mains in open country make proper adjustments of items affected. Backfill based on total depth with street opened to traffic and paving done somewhat later. If paving is to be done along with job, make proper adjustments of items affected. For small jobs during which men assemble at shop and are transported on department time, make proper adjustments of labor costs. Roughly each half hour so consumed adds 6% to labor costs, although other advantages may offset this added cost depending upon number of men involved.—D. R. TAYLOR, Roanoke, Va.

PROTECTING WATER PIPES FROM FROST

By F. J. RENY
Treasurer and General Manager
Portland Water District
Portland Water District

IT IS probable that the first attempt to protect water pipes in a dwelling house from freezing was to allow the water to run to waste. Of course, this method of protecting water pipes is abhorrent to the water works manager and he will find some method to prevent this waste unless he has all the water in the world to run to waste and he figures that it does not cost him anything.

Protecting Meters

Experiences with installations have led to various methods of protection, one being the setting of the meter in the basement and building a wooden box around it, about 18 inches square, and the box being packed with sawdust or some other dry material which will keep the frost out. Others use a "meter-mitten," so-called, which is made of some fibre preparation and is the shape of a meter and can be put around the meter itself, leaving an air space by way of protection. I have never heard that these were successful however. The installation of the meter in a pit outside is usually too expensive, unless it is the only way to install the meter to cover the use in the building.

Our experience with meter pits in the ground outside of the building involves those built of 2-inch hemlock plank nailed together with heavy spikes and heavy cleats to form the four sides of the pit. The bottom is about 4 feet square and the top large enough to fit the iron frame, which is 24x29½ inches and contains a round cover 15 inches in diameter. These can be installed in the usual dirt street or sidewalk for about $35 and they give as little trouble as anything that has yet been devised. Smaller pits have been made of tile and other material but they are not sufficiently frost-proof for our conditions.

In some sections where buildings are set on posts and must be metered we have placed the meter in the kitchen, where heat from the range protected it from frost.

Some have found that where heat is not available in the basement that on cold nights a lighted lantern will generate heat enough, if it is placed close to the meter, to prevent freezing of the meter.

Protecting Service Lines

The following are some of the rather common methods of protecting house services where buildings are not modern and the cellars are not heated with modern ranges or boilers. The most efficient method of protecting a house service, however, is sufficient cover to prevent the penetration of frost to the depth of the pipe. Experiments have proved that services which are laid with at least 5-foot cover are mostly always sufficient unless there is an unusual winter with a long spell of sub-zero weather and with very little snow cover. The lack of the snow blanket results in greater frost penetration and over a short time. We are laying all new water pipes five and one-half feet deep, which seems to be a safe depth.

Pipe Insulating

Many kinds of insulations have been tried by water works to insulate services where sufficient cover could not be obtained and where expensive ledge excavation made the cost very high and it was a question as to whether it would cost less to insulate them or blow out the ledge. I confess that our experience in most cases has been that there is no substitute for installing the pipe below the frost line in the beginning, and many have found to their sorrow that a pipe insufficiently covered is going to give them trouble, and when they awake some cold morning and find the service frozen, they will then have to go to the expense of lowering the pipe to the proper depth. Ledge excavation is no longer the costly job that it used to be, and some local contractors will take out ledge for as low as 75c per foot with their own machinery.

The greatest hazard that we have found in winter time is around the salt water and the wharves. Most of these places are business houses, and where small amounts of water are used and where they cannot afford to pay for water wasted to prevent freezing, and some method must be found so that they can shut off the water at night and drain their service in order to avoid a freeze-up.

A rubber insulation was devised for copper service and tried out by us on several water front locations. Thus far, the rubber covered services have not given us any trouble. Several installations were put in filling stations and in churches where services were held in the church only once a week and where there was no heat during the week. The rubber insulation has served in these cases without giving any complaint.

What a Piece of Plank Will Do

Perhaps the most common form of insulation of water service that has been tried is the method used by the farmer who laid his pipe from the spring to his dwelling house not covered to sufficient depth and in order to avoid freezing he took an ordinary board and placed it on the pipe in the trench and filled in the earth around it. Investigation of this method has proved that the frost will not go through the wooden board and the board will stay a good many years before it rots underground and allows the pipe to be reached by frost. I have seen spring pipes which have been in the ground thirty or more years and with a covering of not more than 2 ft. 6 in., and yet the pipe had never frozen. The board seems to divide the frost when it strikes and the frost goes down on either side. Investigation of this method has shown us that worms will live under the boards through the winter.

Other forms of protection have been tried such as pipe covering or enclosing the pipe in a metal or tile conduit with an air space so that if freezing should occur, it can be disconnected and pulled out, but these are very much more expensive than the simple method of the wooden board. So much for services.

Protection for Mains

In regard to the protection of mains, many interesting experiences can be told about the protection of mains from frost. Most of us have seen water mains which have sufficient pressure and velocity exposed to the air all the year round with no danger of freezing whatsoever, because of the high rate of flow. We have in our Portland system pipe lines where the tops of the pipes are exposed but they have never been frozen. Perhaps the most exposed place in water mains is on bridge crossings where the flow through the night is less and the water in the pipe would be liable to freeze. In many cases, bridge crossings have been insulated in the following manner. A crew recaulks all of the joints to see that they were absolutely tight. Then a heavy coating of ¾ in. felt is wrapped around the pipe and held in place by copper wire. On top of this wrapping of felt there is another wrapping of ordinary 2-ply roofing paper which was also wound with copper wire. Care is taken all the time to break joints so that dampness cannot get in. Another wrapping of felt is then placed about the pipe over the roofing paper and another additional wrapping of roofing paper over this second coating of felt. A copper wire is then wound around the pipe so that the wrappings are about 3 inches apart and then all exposed or open places carefully covered with roofing cement. The entrances of the pipe line into the dirt or stone are also caulked in order to protect them as far as possible. Thus far the bridge crossings which we have insulated in this manner have never given us any trouble.

Water Warming

Perhaps the most interesting experiment in protecting a submarine line was performed by the Casco Bay Light and Water Company of Portland, Me. They send water through a 6-in. line from one island to another, and it was found that the temperature of the sea around the fresh water in the pipe would cause it to freeze because fresh water has a higher freezing point than salt water and therefore it was decided by the Casco Bay Company to slightly preheat the water with an electric heater before it started on its journey through the submarine line to the island, some 2,000 or 3,000 feet away. This experiment was very successfully accomplished.

The protection of water mains from freezing most always brings up the additional question of the protecting of submarine lines and it has been our experience in all cases that submarine lines should be laid in a trench and buried with sufficient cover to avoid the action of the cold salt water.

STREAMLINE PIPE AND FITTINGS DIVISION MUELLER BRASS CO.

Port Huron, Michigan

STREAMLINE Copper Pipe and STREAMLINE Solder Fittings for Water Service Work

In 1924 the Mueller Brass Co. originated and were the first to introduce a product then known as Mueller Copper Service Pipe and Flared Fittings. This was a distinct innovation and was conceded to be the most revolutionary contribution of the time for water service purposes.

Waterworks' engineers and superintendents prefer as soft copper pipe as possible for water service work. STREAMLINE Type K Pipe is consistently and uniformly soft. It is made from Virgin Copper Ingot consisting of at least 99.94% copper and throughout every phase of its manufacture is under rigid and constant laboratory control. From the time we started to manufacture this product in 1924, and throughout the years since, we have produced the best and softest pipe that can be made for water service work.

RUST PROOF

STREAMLINE Copper Pipe is rust-proof and is superior to any other metal for service pipe work. Under normal conditions of soil and water, it will last for generations, and will deliver its full capacity of water free from foreign particles as clear and pure as it is in the water main.

FLEXIBLE

STREAMLINE Copper Service Pipe is exceptionally and uniformly flexible. It can be very quickly and easily bent around comparatively sharp radii without annealing or loading. It may easily be bent around obstructions encountered in the trench with a great deal less cost than would be entailed in removing the obstruction.

REASONABLE COST

Copper Pipe connected with STREAMLINE Fittings is very reasonable in cost, although naturally a little more expensive than rustable pipe. It really costs a great deal less over a period of time, because replacements are eliminated owing to the rust and clog-proof properties of STREAMLINE Type K Copper Pipe.

COUPLING
Copper to Copper

VIBRATION PROOF

STREAMLINE Copper Pipe connected with STREAMLINE Solder Fittings is free from the harmful effects of vibration. Vibration is not localized at the joints as it is with threaded or flared fittings, but is harmlessly dissipated throughout the service line.

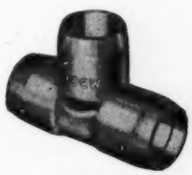
PERMANENT

STREAMLINE Copper Service Pipe is permanent. Once installed it may practically be forgotten; it will give no future trouble. For years it will continue to give the same uninterrupted service and undiminished flow of water.

COUPLING
Copper to Iron

SETTLEMENT AND FROST ACTION

STREAMLINE Copper Service Pipe is so ductile that it will stretch enough to easily take care of any settlement of filled earth, or, in fact, anything that might impose a strain on the service line which would cause failure of rigid ferrous pipe or, at the very least, cause leakage at the threaded connections.



TEE

In the Northern States and in the Dominion of Canada, copper service pipe of our manufacture has an outstanding advantage that places it far in advance of any other service material. This advantage is its resistance to frost action. This service pipe containing water under almost any range of pressure used in water service work can be alternately frozen and thawed out for a considerable number of times without showing any effect except a slight increase in diameter.

STREAMLINE SOLDER FITTINGS

The STREAMLINE Solder Fitting is connected to the pipe by feeding solder through a feed hole in the fitting. Capillarity causes the solder to thoroughly bond the pipe to the fitting and produces an enormously strong joint. This joint is so strong that if, for instance, two ¾" sections of pipe are connected with a ¾" coupling and pulled in the Olsen Testing Machine, it requires approximately 9000 pounds per square inch before a failure occurs, and this failure is always in the pipe itself, and not in the joint. This is, of course, far beyond anything it would be required to stand under actual service.

COUPLING
Copper to Inside Thread

A copy of our catalog, fully illustrating and describing these products, together with simple instructions for connecting, will be sent upon request.

STREAMLINE Fittings are manufactured under Patents 1,770,852, 1,776,502, 1,890,998.

THE ATLAS MINERAL PRODUCTS COMPANY

OF PENNSYLVANIA — MERTZTOWN, PA.

Tegul- MINERALEAD

for Jointing Bell and Spigot Water Mains

Composition

Tegul-Mineralead is a plasticized sulphur compound containing a specially-prepared olefine polysulphide as a plasticizing agent developed by a staff of Chemists, Chemical Engineers, and Civil Engineers whose services are available for recommending, designing and supervising the erection of all types of construction in which Tegul products are used.

How Used

MELTING: Tegul-Mineralead melts at 248° F., requiring only a low fire. Care should be exercised to avoid direct contact with flame and over-heating, in which case the compound tends to thicken. Best results will be obtained when using a furnace designed by the manufacturers of Tegul-Mineralead.

YARNING: The pipe at the Bell and Spigot must be clean and free from accumulations of oil, grease, dirt and tar. If Jute is used, only Dry, Braided is recommended. Sterilpak (described below) is advised because of its many advantages over ordinary yarn or jute.

POURING: See that the joints are clean. Use mud on the asbestos runner to prevent adhesion with the Tegul-Mineralead and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or a pouring pot of sufficient capacity so that the joint can be filled at one operation. Add whole or half ingots to replace Tegul-Mineralead used. It is not necessary to wait for complete melting before pouring more joints. Cut off the pouring gate when the compound has solidified. Remove the runner and the joint is finished.

POURING WET JOINTS: The same general process is used as described above except that the runner must be held away from the bell at the bottom of the joint to provide an outlet through which the Tegul-Mineralead can drive out the water. When the compound flows freely through this opening, close it with clay and continue pouring until the gate is full. Better results are obtained if the Tegul-Mineralead is heated to just below the thickening point.

Advantages

Tegul-Mineralead has greater adhesion to metallic and ceramic surfaces, greater resistance to vibration, mechanical shock and changes in temperature, greater plasticity, and a lower coefficient of expansion than have unplasticized sulphur cements. Tegul-Mineralead has the following specific properties:

1. The "initial" leakage is greatly reduced and a perfectly tight joint is obtained in a shorter period of time. Thus less delay in construction and the elimination of the traffic problem caused by open trenches.
2. Greater resistance to mechanical shock and vibration enable Tegul-Mineralead to stand up under conditions that will destroy lead joints.
3. The resistance of Tegul-Mineralead to sudden changes in temperature is of importance when used in lines exposed to the elements or used for carrying hot water.
4. Permanently tight and trouble-free water line under any ordinary conditions of use.

Tegul-Mineralead is impervious to water, is convenient to handle and to store and is shipped in cartons containing five 10-lb. ingots. Every batch of Tegul-Mineralead is sampled and tested before being accepted for shipment.

STERILPAK—Rubber Packing for Yarning Bell and Spigot Joints in Cast Iron Water Mains

Sterilpak avoids the extreme difficulty often encountered in sterilizing water lines whose joints have been packed with jute or hemp. Sterilpak requires only one thorough chlorination since any bacteria present are on the surface only. Easily applied, dams off water in making wet joints, centers the pipe, economical. Supplied in round and wedge shapes.

Quantities of STERILPAK and Tegul-MINERALEAD required per joint in Bell and Spigot Cast Iron Water Pipe

Size of Pipe	Pounds Per Joint Round Sterilpak	Wedge Sterilpak	Tegul-Mineralead
4″	.29	.27	1.9
6″	.38	.36	3
8″	.48	.44	4.6
10″	.57	.54	5.5
12″	.67	.63	6.5
14″	.77	.72	7.5
16″	1.34	.88	10.1
18″	1.50	.98	11.7
20″	1.64	1.07	12.6
24″	1.95	1.27	14.9
30″	2.40	1.56	18.4
36″	2.85	1.86	22.2
42″	3.30	2.15	29.5
48″	3.76	2.45	33.3

The above quantities are approximate. The Tegul-MINERALEAD quantities will be about 20% higher if there is no bead on the spigot end of the pipe.

G-K SEWER JOINT COMPOUND—A Positive, Permanent, Pliable Pipe Joint

G-K SEWER JOINT COMPOUND is the original bituminous sewer joint. It is not affected by water, sewage, acids or the ordinary constituents of soil. Prevents infiltration, pollution of ground by leakage of sewage, and penetration of roots, such as are found in temperate climates. May be used in cold weather, remains flexible, does not require skilled labor. Successfully used for over 30 years. Shipped in 120 and 270 lb. drums.

Quantities of G-K Compound per joint:

Size of Pipe	Depth of Joint	Cubic Inches of Compound	Pounds Jute	Pounds* G-K
4″	1¼″	8.2	.03	.52
6″	1¾″	19.2	.04	1.22
8″	1¾″	31.2	.15	1.98
10″	1¾″	38.1	.26	2.42
12″	1¾″	48.2	.31	3.07
15″	1¾″	55	.40	3.5
18″	2¼″	83.7	.47	5.31
21″	2¼″	120.1	.65	7.59
24″	2¼″	136.5	.74	8.58
27″	2½″	202.2	1.29	12.87
30″	2½″	250	1.65	15.9
33″	3″	328	1.76	19.5
36″	3″	450	2.44	28.8

*This calculation is based on 10% excess for possible waste.

UNITED STATES PIPE AND FOUNDRY CO.

General Offices: **Burlington, New Jersey**

PLANTS AT

Addyston, Ohio **Bessemer, Ala.** **Birmingham, Ala.** **Burlington, N. J.** **Chattanooga, Tenn.**

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Philadelphia **New York** **Birmingham** **Chicago** **San Francisco** **Boston** **Pittsburgh** **Buffalo** **Cleveland** **Kansas City** **Minneapolis** **Dallas** **Seattle** **Los Angeles**

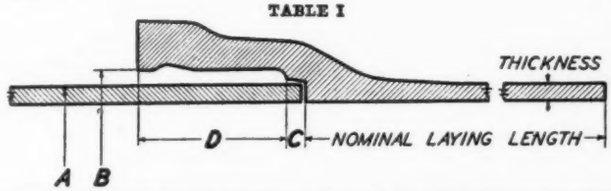
Makers of

SUPER-DE LAVAUD CENTRIFUGALLY CAST IRON PIPE
PIT CAST IRON PIPE AND FITTINGS
THREADED PIPE IN IRON PIPE SIZES
WEBRE INDUSTRIAL AND SUGAR APPARATUS
USICAST CHEMICAL CASTINGS
U. S. JOINT PIPE AND FITTINGS
FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
LARGE CASTINGS TO ORDER
USICAST CAST IRON ROOF

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3″ to 24″ and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8	210	11.7
3	250	.36	155	12.8	230	12.7
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	25.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

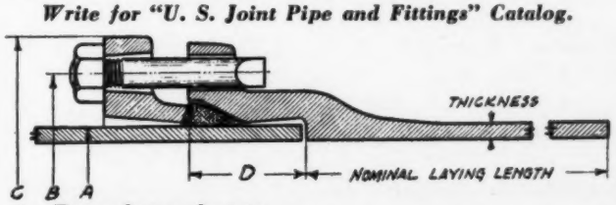
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for "U. S. Joint Pipe and Fittings" Catalog.



1. **Ruggedness of parts.**
2. **High resistance to corrosion since all of the joint accessories are of the same material—cast iron.**
3. **Maximum joint deflection without leakage.**
4. **Great resistance to the flow of electric currents.**
5. **Ease of assembly—needs only one wrench.**
6. **Only one gasket per joint.**
7. **Excellent qualities as an expansion joint.**
8. **Tightness under high pressures of gas or water.**
9. **Connection to plain end existing pipe line without use of adapter.**

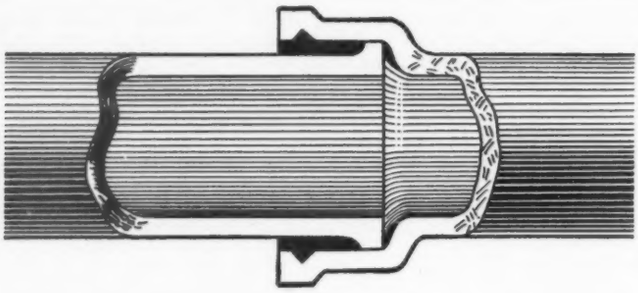
HYDRAULIC DEVELOPMENT CORPORATION

MANUFACTURERS OF HYDRO-TITE—A SELF-CAULKING COMPOUND FOR JOINTING CAST IRON WATER MAINS

MAIN SALES OFFICE:
50 CHURCH ST., NEW YORK, N. Y.

GENERAL OFFICES AND WORKS:
W. MEDFORD STA., BOSTON, MASS.

A Symbol of Quality



HYDRO-TITE does not shrink when cooling but makes a solid bond the entire depth of joint.

Other HYDRO-TITE Features

Self-Caulking: HYDRO-TITE is melted by a small fire and nothing is added to make it liquid. When poured into a joint it immediately solidifies upon contact with the metal and bonds to both the surfaces of the bell and the spigot for the entire length of the joint. HYDRO-TITE requires no caulking.

Self-Sealing: HYDRO-TITE joints are, under normal conditions, perfectly tight when pressure is first applied. Any leak or seep from a new joint will soon be stopped by the self-sealing quality of HYDRO-TITE. Even leaks occurring when pouring over-heated HYDRO-TITE will seal themselves within a day or two. "Less leakage from the start and quicker sealing qualities in case of small leakage."

Ready for Immediate Use: There need be no waiting time after pouring a joint with HYDRO-TITE. It solidifies at once upon contact with the pipe and is ready for regular pipe service.

Resists Vibration: HYDRO-TITE can be used anywhere. It is in service on pipe lines carried over bridges subjected to heavy automobile trucking, trolley cars and continuous railway traffic.

Strength to Support Joints: Flood washouts have many times left entirely unsupported several sections of large pipe and without any leaky joints resulting. In one case, at Fitchburg, Mass., a 30" class B main weighing 4000 pounds was entirely supported from the bell end by the HYDRO-TITE joint after the false work supporting the spigot end had been washed away.

Approved by

HYDRO-TITE is approved and used by leading engineers, municipal water works, water companies, railroads, mines and industrial plants throughout this country and many others. It is also approved by the Associated Factory Mutual Insurance Companies and will be found listed on page 5, their "Rules for Laying Cast-Iron Pipe," issued June, 1929.

Properties of HYDRO-TITE

HYDRO-TITE is a black powder composed of selected inert minerals. When melted and allowed to cool, it becomes a strong, tough, metallic mass. Compressive strength is 6000 lbs. per square inch and its tensile strength is over 650 lbs. per square inch.

Manufacture of HYDRO-TITE

HYDRO-TITE is made in an up-to-date factory with modern machines and by efficient methods. Constant inspection, alert supervision and many years of research by some of the best trained chemical scientists combine to make HYDRO-TITE the leader in its field. This makes possible our continued use of the slogan—"MORE THAN 25 YEARS WITHOUT A FAILURE."

Packing and Shipping

HYDRO-TITE is packed and shipped in 100-lb. heavy burlap bags. Each bag contains a specially treated moisture-proof liner which keeps the HYDRO-TITE dry even though stored in a damp place or transported in the rain.

Other Products

Braided Jute

Yarning Irons

Yarning Hammers

Joint Cutters

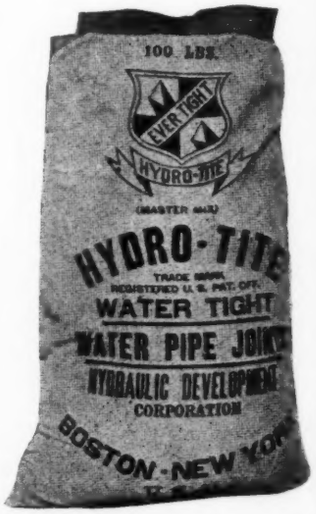
Joint Runners

Open Seam Pouring Funnels

Wood-Burning Furnaces

Pouring Pots

Pouring Ladles



OVER 25 YEARS IN SERVICE WITHOUT A SINGLE FAILURE

TRANSPORTATION SIMPLIFIED

Power Crane-Equipped Truck Makes for Ease and Economy

By D. R. TAYLOR
Plant Superintendent
Water Department, Roanoke, Virginia

THE problem of transportation is one that many of us were confronted with when we began using cast iron pipe 18 feet long. If you have much hauling to do, it will pay you to buy a long wheel-base truck chassis and to have a power crane installed on it and have a platform body built locally to meet your particular needs. Such a truck chassis that we purchased and equipped when we began the use of 18 foot pipe is here pictured. The power crane was obtained from the Baker Equipment Corp., Richmond, Va., who are our nearest agents for the Gar Wood Industries of Detroit.

The truck chassis should have a wheel base of at least 220 inches. The dimensions of our particular piece of equipment are as follows: The length from the back of the cab to the end of the frame is 19 feet. The crane utilizes 3 feet of this space, and our platform body is 17 feet long, allowing the body to project 1 foot beyond the end of the frame. This allows 18 foot pipe to project 1 foot beyond the body with a total overhang of 2 feet beyond the end of the frame. This is permissible and within the bounds of good practice, as recommended by truck manufacturers. For flexibility and economic transportation, I would suggest that you purchase a heavy duty two-ton chassis, with which you can easily haul a load of four tons from your pipe lot to the job in question without abusing the equipment.

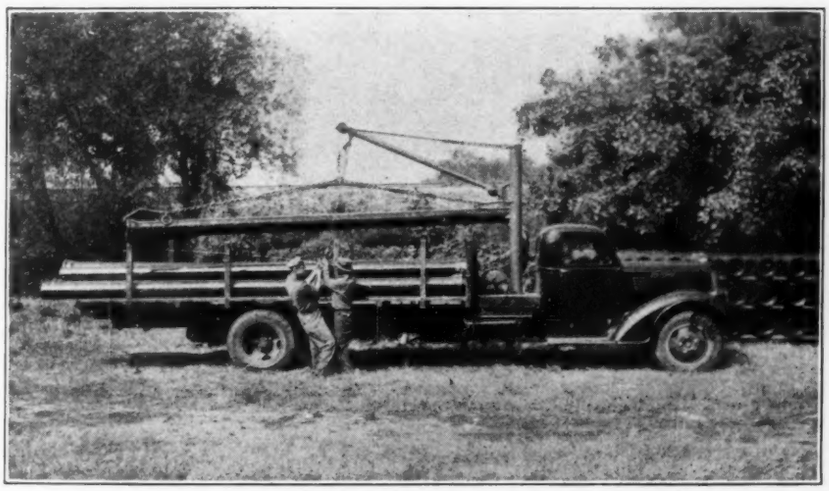
The smaller picture better shows the chain sling with a hook on each end. This was improvised by one of our foremen. The jack, shown in the foreground folded up underneath the crane platform, is one of two furnished with the crane. The jack on the side from which you are raising or lowering the load is unhooked and allowed to swing down to the ground to support the platform while you are loading or unloading.

This crane can be obtained with various capacities and booms of several lengths. I would suggest that you purchase one of 3000 pounds capacity with a 10-foot boom. It may be of interest also to you to learn that the mast and boom is demountable and can be easily removed when not needed.

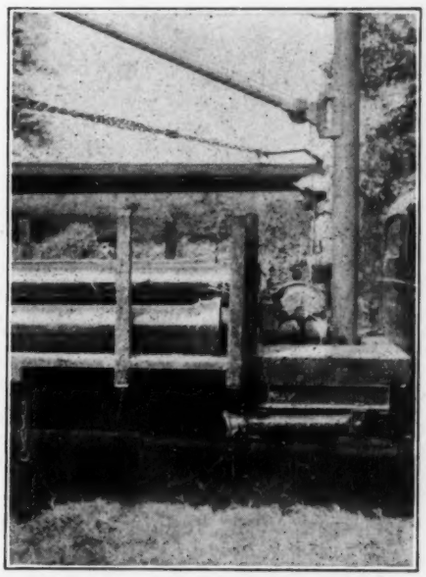
In the good old days, it required six men to unload a car of 8-inch pipe, but, with the outfit described above, three men can do the same job and do it quicker.

If interested in such a purchase and wish any more information, the writer will be glad to give it.

• • •



To Load 18-ft. Lengths of 8-in. Cast Iron Pipe With This Rig Is a Cinch



A Close-Up View Showing Power Crane, the Sling and One of the Support Jacks Beneath the Truck Bed

WHAT LEAKS COST

SIZE OF OPENING	AIR		STEAM		WATER	
	Number of Cu. Ft. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Cu. Ft.	Number of Lbs. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 60c per M Lbs.	Number of Gallons Wasted per Month 40 Lbs. Pressure	Total Cost of Waste per Month @ 15½c per M Gals.
1/2"	17,798,400	$1,779.84	805,000	$483.00	1,231,000	$192.00
3/8"	9,979,200	997.92	460,000	276.00	692,400	108.00
1/4"	4,449,600	444.96	203,000	121.80	307,700	48.00
1/8"	1,114,560	111.46	50,500	30.30	76,900	12.00
1/16"	278,640	27.86	12,750	7.65	19,200	3.00
1/32"	69,552	6.96	3,175	1.91	4,800	0.80

Courtesy M. B. Skinner Co.

BLOWING OUT SERVICE LINES

By S. H. DAVIS

Superintendent, Benwood & McMechen Water Co.
Benwood, W. Va.

Most every water works operator will agree that a low pressure complaint can cause a water company to have poor, or at least "razor-edged," public relations between the affected customer and the company.

However, unless the condition is caused by insufficient main line capacity, the consumer's line, as well as the company's service line, is usually the cause of the low pressure complaint. Attempts to convince the affected customer that he should renew his lines usually brings the following question or statement: "Suppose I do renew my lines, maybe your line is stopped up between the main line and my property. How about you people doing a little digging first?" To answer that question to his satisfaction, usually means to remove meter, if located at property line or curb plot, or cut service line at curb-stop, and let him see for himself. If the pressure is poor and he sees it, he becomes very positive that he won't spend a dime until given better water pressure. He thinks it is high time that the water company correct that condition and he wants it done *"right now."*

Naturally, anyone responsible for the operation of a water company wants the customers satisfied, but on the other hand, he hates to dig into a paved street to disconnect a service from the corporation, or to renew the service line to satisfy the customer.

Method of Cleaning

We have had the usual number of low pressure complaints with all the grief that goes with them. We have tried various methods of cleaning out service lines and the method we now use is the compressed air and rock salt method.

The equipment consists of the following parts:

(1) Cylinder of compressed air—*don't use oxygen.*
(2) 15 ft. (2,000-lb.) wire braided hose with suitable connections to connect to service line.
(3) 1 (2,000-lb working pressure) check valve.
(4) 1 (2,000-lb.) working pressure) forged cross tee.
(5) 1 (2,000-lb. working pressure) angle valve—wheel type.
(6) 1 (1,000-lb.) relief valve—set at 600 to 800 lbs.
(7) 1 (1,800-lb.) pressure gauge.
(8) Necessary nipples to connect fittings and for connections on air cylinder (use extra heavy nipples).

The method of blowing out service lines is as follows:

(1) Make necessary test for low pressure.
(2) Fill wire braided hose with about 2 ft. of coarse rock salt (ice cream salt) and connect to service line with curb or meter stop in the off position.
(3) Close angle valve on tank connection—hose.
(4) Open curb or meter stop.
(5) Just crack needle valve on compressed air tank and then close *quickly* with one hand.
(6) Open angle valve *immediately* with other hand—the "shot" is fired.
(7) Allow muddy water from service to blow through angle valve until water is clear.
(8) Connect up line.

It is advisable to "crack" a nearby fire plug so that the excess air will go out through plug.

The action of the compressed air is very quick and a surging will be noticed in the armored wire hose, but after a few seconds the surging will stop and the water will flow out of the angle valve with normal pressure. As the rock salt enters the service line it literally scrapes the incrustation away from the line and the rock salt dissolves in the main line. No complaint of salty taste in the water has resulted, however.

This system is only recommended where lead or copper service lines have been installed. There is too much danger of rupturing a weakened steel line which is badly corroded.

The photographs show the results of this method. The height of water above ½-inch riser pipe (30 in. above curb stop) was 3 in. only. But, after blowing out service line the height of water was 36 in., indicating increased pressure and volume obtained.

We have found that after we do our part, should the pressure continue low, consumers become convinced that their piping is either corroded or too small. In most cases they will remedy their condition. We do not blow service lines from cellar to property line, because we feel that is the plumber's job.

The average time required to attach the equipment and blow out a service line is only 15 minutes. Our cost for a cylinder of air is approximately $2.50.

Dribble *Load* *Shoot* *Gush*

One That Needs Blowing; Loading Armored Hose with 2 ft. of Rock Salt; the Quick Shot of Compressed Air (Note Man with One Hand on Cylinder Valve, the Other on Release Angle Valve). Results—Plenty of Water and a Satisfied Customer.

SCHRAMM, INC.

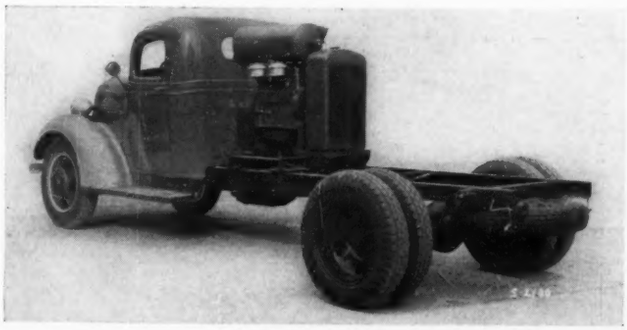
Manufacturers of Portable and Stationary Air Compressors
WEST CHESTER, PA.

Application: Portable gasoline driven compressors for water and sewage repair and maintenance crews. Compressed air for the operation of pavement breakers, rock drills, clay diggers, back-fill tampers; for air-caulking and chipping hammers and other pneumatic tools; for blowing mains to be repaired, service lines or scour flushing small mains.

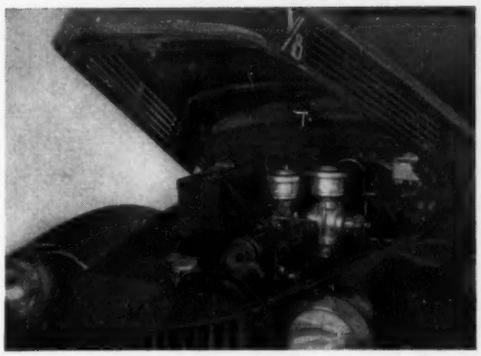
MODEL 60 TWO WHEEL TRAILER

Designed for rapid and inexpensive transportation behind truck or car. Equipped with universal coupling and drop leg. Can be mounted on wood skids for use in truck body.

Specifications: Capacity—60 cu. ft. per min. actual air delivery at 100 lbs. gauge pressure. Engine—Four cylinders of Mercury V-8 Bore and Stroke, 3 3/16"x3 ¾". Compressor—Four cylinders of Mercury V-8 Bore and Stroke, 3 3/16" x3¾". Speed, 1,390 R.P.M. Accessories—Hood, side doors, radiators and guard, battery and starter, generator, oil bath air cleaners on engine and compressor, panel board with all gauges, and spring tailer with semi-elliptic springs and pneumatic tires.



MODEL 60 POWAIR



Puts a model 60 compressor unit in your Ford truck without *any loss of trucking* or driver space. The compressor unit replaces the regular Ford V-8 engine. The engine that drives the compressor drives the truck. A simple control operation in the cab with motor running shift from compression to driving and back. The installation is made by the customer or a local Ford Dealer.

MODEL 105 POWER TAKE-OFF

105 C.F.M. at 100 lbs. Pressure

Compressor is located on truck body and is driven by the regular truck motor through a power take-off. Easily and economically installed. Designed for use with engines 221 cu. in. or larger. Engine speed governed only when compressing.

MODEL 315 DIESEL ENGINE DRIVEN COMPRESSOR

Built in sizes ranging from 20 to 420 cu. ft. of actual air delivery, SCHRAMM compressors are available for any requirements no matter how large or small your job might be. Every possible type of mounting is also available including rubber tire, with or without spring trailer for high speed towing—two wheel trailer type—mounting for any standard make of truck. Outfits are obtainable for gasoline engine drive or with standard make Diesel engines.

DE-WATERING MAINS WITH COMPRESSED AIR

Eliminates Pumping, Wet Trench, Loss of Time

By ARTHUR C. KING

Superintendent of Water Works, Taunton, Mass.

IN THE 1939 Reference Data Issue of "WATER WORKS AND SEWERAGE" an article by Roger W. Esty and Nelson Boardman of Danvers, Mass., describes the use of compressed air for removing water from mains.

Here in Taunton, Mass., we have adopted the method, developed by Esty and Boardman, and have successfully used it on pipe of such size that we believe our experience might be of interest to others who may have questioned the value of the scheme for mains of larger sizes. (See sketches on next page.)

An Experience with a 12-Inch Main

It became necessary to relocate about 600 feet of 12" cast iron main. Since occupied buildings were supplied from the section to be relocated, it was decided to lay the new main before cutting off the old for salvage.

After the new pipe was laid, the problem was that of making the connections between the old and new as quickly as possible, both on account of regular use and also the reduction in fire protection during the change-over. The section to be drained (about 2500 ft.), lay on an up-grade, as will be seen on the accompanying sketch (a), and hydrants were already in place at the high end and near the low end. The main was shut down, the hydrant near the low end was opened, and the air compressor connected to the hydrant *at the high end*. In a surprisingly short time, perhaps 40 minutes, although it was not timed, water ceased to come out of the hydrant and the main was cut. No water came out through the cut. The old and new sections were connected and the water turned into part of the new main within 4 hours, restoring service to all buildings. The upper end was then cut off and reconnected. Not a bit of ditch pumping was required.

We Try a 16-inch Main

Another large main de-watered with compressed air was of 16" cast iron. The length between gates was about 1200 feet—see sketch (b). About 800 feet was on a slight up-grade to a summit, where there was a hydrant. The other 400 feet was on a downgrade to the point of cutting, with a hydrant in that shut-down section just beyond the cut. The low hydrant was opened and the compressor connected to the hydrant at the summit. The water was quickly driven out and the cut made. In this case, apparently some gate was not shut quite tight as a trickle of water occasionally came out, but it was not enough to make trouble for us. We considered this job also a remarkable demonstration of the Danvers method.

On second thought, another hydrant might have been opened to de-water part of the main on the slope back from the summit away from the work, before the cut was made. Then the leakage would have accumulated back of the summit.

We Do a 20-inch Job

On another occasion we used the air to empty about 700 feet of 20" cast iron pipe, sketch (c). The upper end was nearly level for about 200 feet then the pipe sloped down from a hydrant at the summit about 500 feet past the work to be done to a hydrant at the low end. Here again no difficulty was experienced and the water was driven out very quickly, but was not timed.

We also drained about 1200 feet of 12" cast iron shown on sketch (d). In this case we cut out and replaced an 8" gate valve on a branch main a few feet away, and on an up-grade, from the 12" main. The whole job of de-watering, cutting out the old and inserting the new gate, was completed in less than 2 hours.

Our compressor is set for a maximum of 95 pounds pressure and starts up when the pressure drops about 10 pounds. We did not note what pressure was held during de-watering, but there was no indication of lack of air or pressure for these lengths of 12", 16" and 20" mains. The rated capacity of our compressor is 110 cubic feet per minute.

The scheme proved its worth very effectively.

IMPROVED METHOD OF MAKING WET TAPS

By E. T. CRANCH

Manager, New Rochelle (N. Y.) Water Co.

It is assumed that all waterworks men are familiar with the ordinary hand operated machines for the making of wet-taps.

The hand operated machine, while a great convenience was, however, tedious to operate. A six or eight inch tap would take two or three hours to cut and the larger taps much longer. It would also take not less than three men, working in relays, to operate the machine successfully.

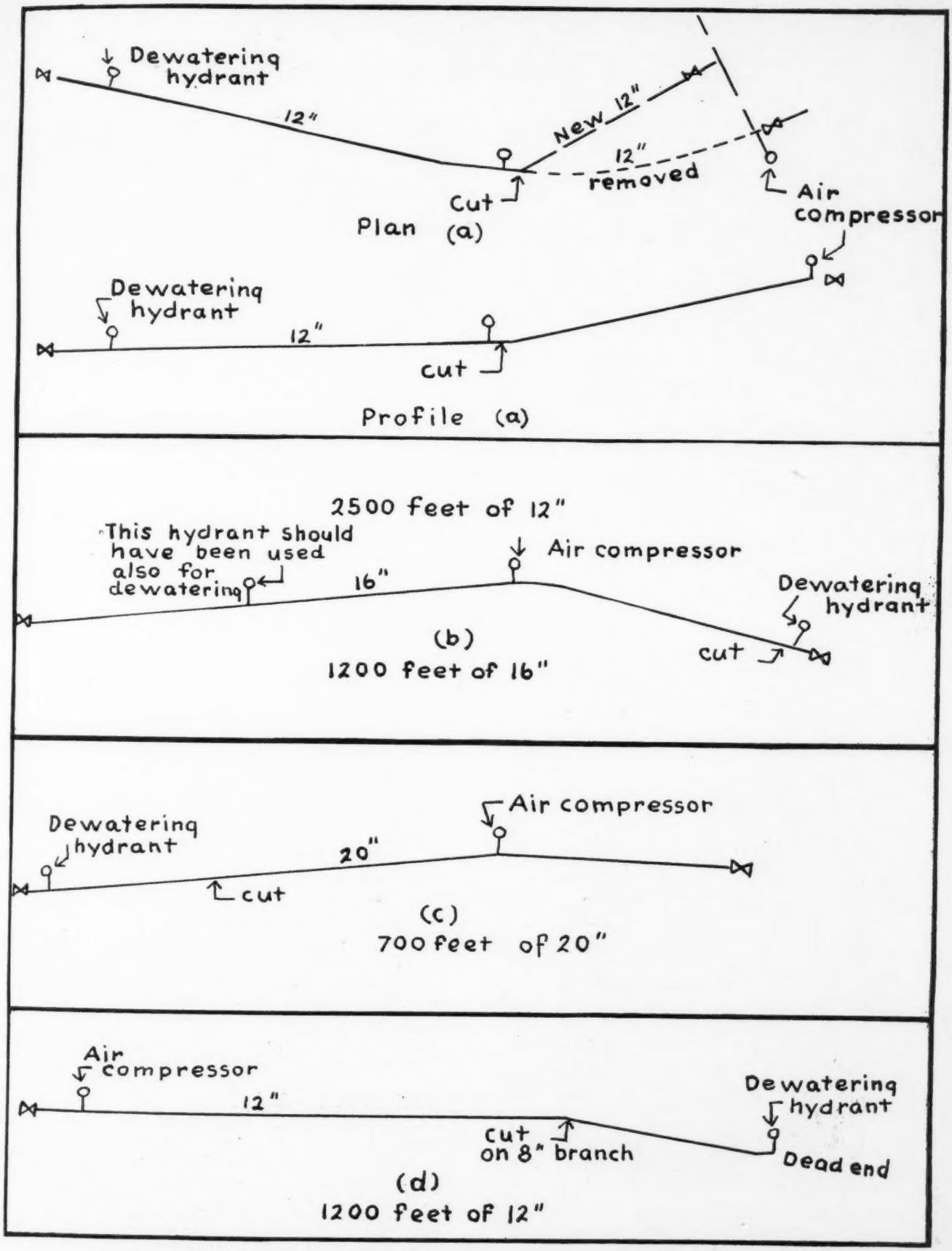
For plants which carry an air compressor unit in their equipment, there is now a means for making these taps quickly and easily. The old hand-type machine can be readily equipped with a bracket to permit the use of a compressed air motor and with a three-horse air motor an eight inch tap can be made in less than half an hour. With this arrangement it is also possible for one man to operate both the motor and the drill feed.

Equipping the machine with the motor-drive does not interfere with its continued use as a hand machine whenever conditions warrant, or should compressed air not be available at some time. It is only necessary to unscrew four stud bolts and remove the motor bracket. The machine is then ready for hand operation as before.

With the use of the air operated tapping machine we have recently made an 8-inch connection to a 12-inch main of class "B" pipe. In timing the whole operation it took just 90 minutes from the time the men started to place the sleeve on the pipe until the job was completed and the machine removed. The actual drilling time was, in this case, only 11 minutes.

The accompanying illustration is a picture made on an earlier job. The tapping machine, which is not new, was purchased some years ago from the A. P. Smith Mfg. Co. The compressed-air motor was supplied by Ingersoll-Rand Co.

DEWATERING MAINS



Sketches Revealing Conditions in Main-Dewatering Experiences Employing Compressed Air.

SELECTING THE RIGHT METER

By ROGER W. ESTY

Superintendent, Water Works and Sewerage, Danvers, Mass.

In days gone by, the thought of "What shall we set for a meter on a service line?" was not given the consideration warranted. The expense involved apparently did not appear to be a factor, because the size of the pipe installed was generally used as the determining factor in selecting the size of meter for the installation.

Since those days meters have reached a much higher degree of perfection and now, at reasonable cost, meters can be purchased to fit any service required; and, can be depended upon to give satisfactory results.

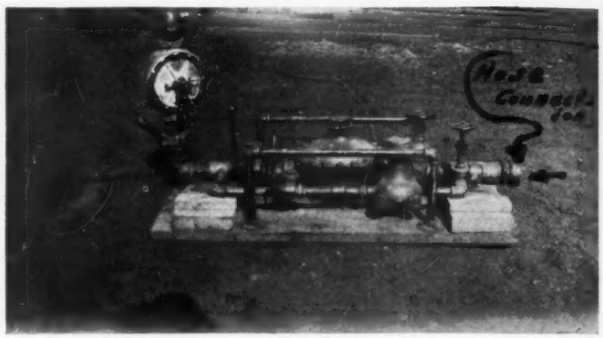
Especial care should be exercised when purchasing a meter because this device serves as the cash-register of the system. When purchasing a meter do not let the price be the determining factor; for, as you know, the older we get the more and more do we realize that you get just about what you pay for. There is no such thing, nowadays, as truth in a claim that "It is just as good for one-half the price."

We must not forget the obligation we owe to those we serve. We must not spend their money recklessly or unwisely.

Several years ago, at Danvers, we had a water waste survey made to check up on our consumption, which apparently was gradually creeping upward without any particular reason. Much to our surprise, we found no unreasonable leakage, but found that all of our large meters were under-registering, some as much as 50 or 60 per cent. On large meters this constitutes a sizeable and serious loss.

In the past, we never tested these meters. And, as long as they kept running and the monthly readings were comparative little, if any, attention was given them. When we found a stopped one we would take it apart and clean it and make whatever repairs found necessary. We didn't know whether the meter recorded accurately or not. We merely assumed that if it was properly cleaned and repaired it must be right.

Neptune Recording Meter Set, Used in Evalulating Variations in Water Takings by a Customer and Determining the Proper Capacity of Meter



Portable Meter Testing and Flow Measuring Outfit Used in Field Tests

After our water waste survey we changed practically every meter. Some we had rebuilt. As time went on we found that this change had been very unsatisfactory. We were suspicious of the accuracy of the readings of one large meter, realizing that its registrations must be too low. To obtain a test on it, we put in two one-inch corporation checks, brought them together, and then from this junction extended a fire hose to a two-inch test disc-meter which had been previously checked for accuracy. From this set-up approximately 200 g.p.m. was obtainable. Apparently our suspicions had been right because we found the meter under-registering. As a result of that test, we started tapping in just beyond all of the other large meters for additional testing.

Meter By-Pass Lines Proved Their Worth

From the results of this work, we decided to take out all of our institution and industrial meters, replacing them with new meters. In each case we provided a by-pass line, a test tee and the necessary gates, so that tests and repairs could be made at any time without inconvenience to the customer.

In my opinion the money spent constituted the best investment we have ever made for convenient and money saving maintenance. It is a highly justifiable expense and no meter of any consequence should be set without being provided with a properly gated by-pass with a test plug inserted.

We made mistakes in our first set-up that I would correct if I had to do the work over again. In making changes my first correction would be to set the meter on the by-pass, line and leave the main line unobstructed, to take care of large emergency demands such as would be needed at a fire. As a general rule, a meter much smaller than the size of the supply pipe can be, and should be used and there is also a saving to be had in the cost of the smaller fittings required. This is now the practice followed in Danvers.

Then, next, all gates should be provided with rising stem valves. There is a possibility of leaving gates opened or closed where the standard (non-indicating) gate stem is used. Visualization is a great safeguard and protection and at a glance one can tell the position of a rising stem valve.

Oversize Meters—Why?

After this new set-up of meters had been in for a few years, we made a 3 or 4 day test on each meter, running the recording testing device twenty-four hours each day. The results were surprising—even astounding. Meter line requirements on 6 and 8-inch pipe lines, provided with meters of the same size as the pipe, showed that at no time did the demand exceed on the 6-inch meter 25 g.p.m. and on the 8-inch meter 75 g.p.m.

From these results it was apparent that: In the first case a ¼-inch meter would amply take care of the normal demands on the 6-inch service; and in the second instance a 1¼-inch

meter would suffice on the 8-inch service. But, these meters were on lines supplying hydrants, and therefore the smaller meters could not be used. It is my opinion, however, that a 4-inch meter—if not a 3-inch meter—will prove ample. A 3-inch meter on a by-pass will supply two powerful fire streams and in most cases this will be sufficient. If a greater demand should be required the main line can be opened. Since we have a man who answers every fire alarm, he has been instructed in every instance to open up the gate on the unmetered side, regardless of how small the first might be.

We have had these smaller meters in now for nine years and we have only opened up the unmetered side of the line once. At this fire only one stream was used, but the gate was opened just the same. No difference was noticed in the volume in this instance, where a 3-inch meter had been cut into a 6-inch line leading from an 18-inch main.

What Size Service Line?

When laying a service main I thoroughly believe in laying one that will more than take care of the service demanded. Larger lines reduce friction and deliver volume up to the point of the demand. The owner should be interviewed regarding what he feels will be his maximum demand in gallons per minute. On commercial lines, I try to have the customer visualize a barrel and then tell him that that barrel holds 50 gallons. Then I ask, how much more or less than 50 gallons per minute will he use? He can readily make a comparison in his mind between the 50 gallons and the amount he is going to use and he can then easily judge about how much he will use, and it is seldom you will find any user using more than "a barrel a minute." Cubic feet means nothing to the customer, and even gallons per minute means little, but the barrel method of determining the amount of water he might use, is much easier for him to understand and has not failed yet in giving to me the information that I have wanted in determining the size of meter and service needed.

The type of service and demand, should be instrumental in determining the type of meter that should be used. Consideration of the small flows should be given prior consideration because 90 per cent of the flows come under the range of the smallest capacities of the large meters. If a large continuous flow is used, then naturally a meter to register large flows should be used as there are no small streams to be considered.

I have a case in my own system, at Danvers, where all of the water is repumped and this pump operates at about 500 g.p.m. until the tank is full, then it automatically shuts off and no more water passes through the meter until the level of the tank drops sufficient to kick in the automatic pump switch. In this case a meter to pick up minor flows, leakage, etc., is not needed, because the rate of flow is 500 g.p.m. or nothing.

The selection of the meter, should in my opinion, be left with the water works officials and *not* to the customer. The ownership of the meter should also be retained by the water department and *not* by the customer. By experience, water works managers are much better qualified than anyone else to select the proper meter which, in justice to all, must be the most adaptable to the desired type of service it is selected for.

[For choice of the correct size of service line for a given demand a useful chart appears in Part III of this issue.—Ed.]

Renovating Water Meters

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

WATER METER TESTING PRINCIPLE AND PRACTICE

[*From "Testing Water Meters—Why and How"*]*

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a ⅝ inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business.*

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*A booklet distributed by Ford Meter Box Co., Wabash, Ind.

MFGR. NO. CO. NO. MAKE SIZE

DATE PURCHASED STYLE

INSTALLATION RECORD								TEST AND REPAIR RECORD								
INSTALLED		NAME	ADDRESS	Tap No.	Reasons for Removal	Removed		Date	Rate of Test			Repairs		Total Amt. of Water Passed Before Test	Tested By	REMARKS
Date	Reading					Date	Reading		Min. Flow	Inter. Flow	Max. Flow	Before Test	After Test			

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more irequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. **Insert Meter in Tester**—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. **Flush Meter Out With a Large Flow**—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. **Bring Test Hand of Meter to a Mark**—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. **Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.**—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. **Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.**—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. **Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.**—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. **Make a Record of the Tests**—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the previous page.

IMPORTANCE OF TESTING DISC METERS AT THE CORRECT RATES OF FLOW

By P. S. WILSON

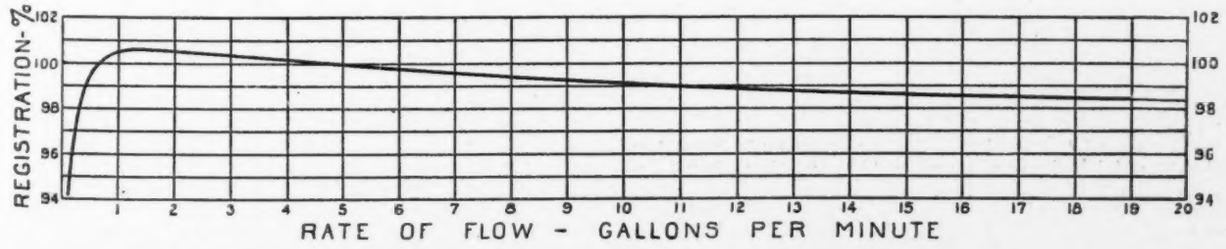
Water Works Consultant, Glen Ridge, N. J.

A TYPICAL registration curve of disc type water meters is shown. In this curve the percentage of the water actually registered during passage through the meter is plotted against the rate of flow in gallons per minute.

The curve as a whole may be shifted upwards or downwards by altering the gearing of the meters but this will not change the general shape of the curve. The curve shown in the figure is drawn for five-eighths inch meters but the corresponding curve for any size of disc meter will have much the same shape in relation to the total range of capacity of the meter. The important fact to observe regarding this curve is the fact that it is a curve and not a straight line. In other words, even above the low flows which the meter will not register, the percentage registered is not the same at different rates of flow.

Importance of Testing at Several Rates of Flow

The purpose of testing a meter is to determine the percentage of the water passing the meter which is registered by it. As explained above, this percentage is normally different at different rates of flow. In routine meter shop practice it is of course impractical to test a meter at every rate of flow under which it will actually operate, and yet we must have assurance that it will register within the limits of accuracy adopted at all of these different rates. We know that a test at a single point on the curve, that is, at a single rate of flow, will not give us the percentage registered at other rates of flow. The curve may be of different curvature depending upon the condition of the meter, and we are making the test because we do not know the condition of the meter. If the clearances in the disc chamber are too great, for example, the meter will not register the low flows well and its curve will drop off too rapidly at that end. If the "control" is not close enough, that is, if the spindle is not held at the proper angle, the meter's registration curve will in all probability go up too high at the intermediate rates of flow. With the multiplicity of parts in a meter there are of course many other defects which may have various effects upon the performance of the mechanism as a whole.



Curve Showing Accuracy of Meter Registration at Variable Rates of Draught.

The endeavor must be to test the meter at the least number of rates which will serve to indicate with sufficient reliability what the performance will be over the rest of its range of capacity. It has been found that in normal practice it is necessary to make a test at each one of the three different rates of flow, unless the condition of the meter is already quite well known. In order to obtain reliable information from as few as three different rates of test, these rates must be carefully chosen in order to show up the true form of the curve and to know that there are no irregularities in it between the points located by the tests.

The three rates of flow at which a disc meter should be tested are usually termed the "Low" or "Minimum" test flow, the "Intermediate" or "Medium" test flow, and the "High" or "Full" flow.

Minimum Flow Test Requirements

The "Low" or Minimum" flow test is made in order to determine that the meter does not drop off in registration at any higher rate of flow than economically possible, in other words, the meter must be able to register down to a certain predetermined low rate with sufficient accuracy. The accuracy of registration at low flows depends to a large extent upon the reduction of clearances and at the same time the avoidance of friction in the meter.

The rates of flow called for as "Minimum Test Flow" in the Standard Specifications for Disc Type Meters as adopted by the American Water Works Association and the New England Water Works Association, and reproduced herewith as Table I, are the rates of flow in common use. Different organizations vary somewhat the required percentage of registration at these flows to suit individual views and conditions. The Standard Specifications referred to call for at least 90 per cent registration at minimum test flows. Good manufactuirng methods and skillful repair work can be considerably better than this on both new and repaired meters, 94 per cent or 96 per cent being not unreasonable to expect.

TABLE I

Rates of Test Flow. From Standard Specifications for Cold Water Meters, Disc Type, Adopted by the A. W. W. A. June 19, 1921, and by the N. E. W. W. A. Sept. 14, 1921

Size of Meter (Inches)	Normal Test Flow Limits (Gallons per Minute)	Minimum Test Flow (Gallons per Minute)
⅝	1 to 20	¼
¾	2 to 34	½
1	3 to 53	¾
1½	5 to 100	1½
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1000	12

Intermediate Flow Test Requirements

The Intermediate test flow should be chosen so as to ascertain that the registration at the high point of the curve does not go too high. The rates should, therefore, be such as to aim for the probable highest point. This will vary with different makes and types of meters but it will usually be found at, or a little higher than, the lower figure given under "Normal Test Flow Limits" in the Standard Specifications—see Table I. For a five-eighths inch meter the table gives 1 gal. per min. and the test flow should usually be from 1 to 2 gal. per min.

If the meter is geared and fitted so as to maintain a good registration at the low and high flows then the difficulty in most cases will be to keep the registration down at the intermediate flow. The flatter that the curve for the meter is, the less need there is for such practice. This is one of the many things to be considered in selecting a meter.

High Flow Test Requirements

The high flow test is considered by some to be the least important. This is unfortunate because it is the quickest and most convenient to perform. The exact rate of flow to be used at this test certainly is less important than with the low and intermediate tests because at rates of flow above the intermediate the curve is not apt to rise or fall so markedly. Many shops use a high test flow equal to the higher figure given under "Normal Test Flow Limits" in the standard specifications (Table I). For a five-eighths inch meter the 20 gal. per min. flow is approximately the maximum rated capacity of the meter. The practical objection to using this figure for the high test flow is that in very few cases will the service pipe and plumbing in a residence pass nearly so high a rate of flow and we are therefore testing at a rate beyond that at which the meter will ever operate. Between 50 per cent and 75 per cent of this high figure is a more logical one to use for testing in routine procedure. At the high flow the percentage registered should again be kept up, as in the low flow, and a minimum of 98 per cent is often specified in accordance with the standard specifications.

Having given consideration to the reasons for choosing each one of the three different rates of test flow it is of course self-evident that it is of equal importance to actually perform the tests at those rates, in other words, to measure with reasonable accuracy just what the rate of flow is during the test and to adjust it to the correct figure.

TABLE II

Discharge of Orifices in Gallons Per Minute. The Smaller of the Two Figures Given in Each Case Is the Discharge of a Sharp Edged Orifice in a Thin Plate. The Larger Figure Is the Discharge with Properly Rounded Edges

Size of Orifice— Inches	Pressure—Pounds Per Square Inch— 40	60	80	100
1/32....	0.11— 0.18	0.13— 0.22	0.16— 0.26	0.18— 0.29
1/16....	0.44— 0.74	0.54— 0.90	0.62— 1.0	0.70— 1.2
1/ 8....	1.8 — 3.0	2.2 — 3.6	2.5 — 4.2	2.8 — 4.7
3/16....	4.0 — 6.7	4.9 — 8.2	5.6 — 9.4	6.3 —10.5
1/ 4....	7.1 —11.8	8.7 —14.5	10.0 —16.7	11.2 —18.7
5/16....	11.1 —18.5	13.6 —23.	15.7 —26.	17.5 —29.
3/ 8....	16.0 —27.	19.6 —33.	23. —38.	25. —42.
7/16....	22. —36.	27. —44.	31. —51.	34. —57.
1 /2....	28. —47.	35. —58.	40. —67.	45. —75.

Importance of Accurately Measuring Flows

The most frequently used means of determining the rate of test flow is with an orifice. No fault can be found with this means if we really know how much water is flowing through the orifice.

The rate of flow through an orifice of a given size depends principally upon the shape of the edges of the hole, the thickness of the plate in which the hole is drilled, and upon the effective pressure acting to push the water through the hole. Rather than to state the size of the orifice it is far more definite to give the rate of flow in gallons per minute, or as the number of seconds to pass one cubic foot, as is done in up to the minute shops.

Table II gives the uncertainties of using orifices which have not been actually tested under fixed and known pressure. For example, a one-sixteenth inch orifice under a pressure of eighty pounds per square inch may discharge as much as one gallon per minute if the inner corners of the hole are properly rounded. On the other hand, if the edges of the hole are sharp and square and the plate through which the hole is drilled is thin the discharge may be less than two-thirds of a gallon per minute under the same pressure. Variations in the effective pressure added to the above uncertainties will of course cause even greater indefiniteness in the discharge. At forty pounds per square inch the discharge of the one-sixteenth inch sharp edged orifice may be considerably less than one-half gallon per minute, while an increase of the pressure to one hundred pounds per square inch will produce a discharge through the same orifice with round edges of over two and one-half times as much. Such uncertainties as these will greatly nullify the benefits of otherwise careful testing.

The best way to determine that the correct rate of flow is being used is to actually use a watch, and preferably a stop watch, to time the filling of a calibrated can or tank. The test flows should be stated in terms of definite figures, such as gallons per minute, and not in terms of the size of the orifice or the number of turns of the valve wheel.

The figures given in Table II are the theoretical figures as to the discharge in gallons per minute of different sizes of orifices under different pressures. The smaller of the two figures given in each case is the discharge with a sharp edged orifice in a thin plate, or with the edges properly bevelled on the outlet side. The larger figure is the maximum discharge to be expected with properly rounded edges on the inlet side of the orifice. These figures may serve as a guide in the choice by trial sizes of orifices to be used for obtaining certain rates of discharge. Actual measurement and timing should be employed to check each one, however. It must be remembered that the pressure which is effective upon the orifice will only be shown correctly by a gage located next to the orifice, and beyond the meter being tested, also that the pressure reading must be taken after the flow has become steady and constant.

WATER WASTE SURVEYS

By A. D. STALKER*

Waste control, as a subject, can be divided very conveniently into two parts: First, that having to do with wastage which takes place inside houses and other buildings; and second, that concerned with wastage from the underground portion of the distribution system.

Meterage as a Remedy

By far the most effective method of dealing with the wastage that takes place inside buildings is by having services 100 per cent metered.

In cities or towns where none, or only a small percentage of the services are metered, the control of waste from defective plumbing fixtures is much more difficult. Systematic house-to-house inspection, regularly maintained by a permanent staff of inspectors, will prove a great aid in keeping this class of waste within reasonable bounds. These inspections must be frequently repeated, and to be effective must be supported by strong laws and good plumbing ordinances.

The public in general seems to think that the information contained in educational literature dealing with the importance of attending to small leaks and wastes should make a great impression—on somebody else. The value of this type of waste-control work is debatable. The writer's opinion is that the results obtained are not worth the trouble and expense of getting up and distributing the literature. *The only cure for waste due to carelessness is metering.*

The Pitometer

The second phase of waste reduction has to do with the location of leakage from the underground portion of the distribution system. To find the leaky parts of the underground system, a survey must be made to ascertain where the water goes after leaving the pumps, and what parts of the system receive excessive quantities. This can be accomplished by means of a pitometer.

The pitometer is an instrument that adapts the "Pitot" principle to the measurement of water. Two tubes enclosed within a metallic sheath are introduced into a water main through a 1-in. corporation cock. The tubes are set in such a position that one orifice faces directly up-stream and the other directly downstream. They are connected by means of rubber tubing to the two legs of a glass U-tube containing a liquid of a specific gravity higher than water and which will not mix with it. The difference between the pressure on the downstream and on the upstream orifices, which is the pressure due to velocity, causes a deflection of the liquid in the arms of the U-tube, and from this deflection the flow is calculated.

The prism photo recording pitometer makes a continuous photograph of the U-tube fluctuations upon a sheet of sensitized paper attached to a drum revolved by clock-work. The drum can be geared to complete a revolution in 12, 24 or 48 hours. From this photo record the flow through the main can be ascertained for any time during the gauging.

To measure accurately the flow through mains with the pitometer, the ratio of the mean velocity to the center velocity must be established, as the orifices of the instrument are set at the center. This ratio is called the "pipe coefficient" and is established by traversing the pipe. A pipe traverse is made by taking readings of the velocity at intervals across the pipe sufficiently close together to make a smooth curve when plotted. The pipe section is divided into rings of approximately the same area. The mean velocity of each ring in feet per second multiplied by the area of the ring in square feet, gives the ring volume in cubic feet per second. The mean velocity for the whole pipe section is the total of these ring volumes divided by the area of the pipe. The mean velocity divided by the center velocity is the pipe coefficient. On large mains it is desirable to traverse the pipe on two diameters 90 degrees apart and in the same plane. By using two rod meters, one can be left at the center of the pipe and the traversing done with the second, and readings taken when the center velocity is the same in each case. The pipe coefficient is the same for all velocities in the same pipe at any particular point, and it is upon the discovery of this principle that all pitometer gaugings are based.

*The late Prin. Asst. Water Works Engineer, Ottawa, Ont.

How Pitometer Survey Is Made

A pitometer survey should properly start at the pumping stations, and the discharge from the pump checked. When this has been done, I think it good practice to test all trunk or feeder mains before dividing the system into districts. These mains taken separately can be quickly done, and the distribution of water through that part of the system fed by them is interfered with for a much shorter time than would be the case if they were to form part of a district. Furthermore, trunk mains are usually so spaced as to form excellent district boundaries.

More accurate results can be obtained if the pitometer tap is placed on a small main feeding into the trunk main than would be the case if the tap were to be placed on the trunk main itself, as a flow that would cause scarcely any deflection of the liquid in the U-tube if the tap were on the large main, would cause a sufficiently great deflection to give an accurate measurement of the flow if the tap were on the smaller main. The tap may be placed in such a position as to serve as a gauging point both for the trunk main and one of the districts.

The next step is the dividing of the system into districts. This work must receive careful consideration. A district should be of a size that can be conveniently sub-divided in one night during the hours of minimum consumption, and the boundaries laid out with a view to causing as little interference as possible with the circulation through the balance of the system. The gauging point should be on a main of such a size that a velocity of about 4 ft. per sec. would supply the maximum normal demands of the district, without any allowance for leakage. This velocity will give a deflection of about 17 in. on the U-tube, using a liquid of 1.25 specific gravity. The maximum consumption would not be likely to cause a velocity great enough to blow the liquid out of the tube, and the minimum consumption would cause a fairly high deflection. When the district is first gauged, a velocity higher than the above will probably be recorded ,and a heavier liquid might have to be used. The idea behind choosing a main of this size is to ensure a deflection high enough to give an accurate measurement of the flow when all leaks have been stopped.

If the survey being made is an original one, a 48-hour record should be taken, including a Sunday if possible. Very careful records should be kept of all flows recorded and work done, and of any peculiar or unusual conditions that may be found to exist, as this information will, without doubt, be of great assistance in later surveys. Weather conditions and any circumstances which might affect the consumption of water should be noted.

When the flow is to be gauged, the district is cut off from the rest of the distribution system by closing all the valves on the boundaries, excepting on the pipe to which the instrument is connected. To make sure that the valves are holding properly, and that no water is getting in, either through them or through services that may be joined up inside buildings and connected to mains on both sides of a boundary, the main feeding the area enclosed should be closed and a hydrant at the highest point within the boundaries opened. If the hydrant is not off, the point at which the water gets into the district must be located, and the flow stopped. When it is assured that the whole supply passes through the main to which the instrument is connected, the district is ready for the taking of the record. Precautions should be taken to prevent street flushers drawing water from hydrants located within the district boundaries while the record is being taken. It is advisable also, to have a man with a valve key stationed at a fire hall either in or convenient to the enclosed area, so that valves could be opened with as little delay as possible in the event of a fire breaking out. If a fire occurs in a district while the flow is being recorded, the record will be ruined, and opening the boundary valves cannot make it any worse.

If the record taken indicates that an excessive amount of water passes the gauging point, and that the flow remains high during the hours in which very little water would be used, the district should be sub-divided. For subdivision purposes the mechanism revolving the drum of the pitometer is geared to complete a revolution of the drum in twelve hours. This will give a movement of an eighth of an inch in five minutes.

One method of sub-dividing is to divide the whole district into

See also "Water Waste Surveys," by Edgar K. Wilson, page 264, Magazine Section, this issue.

sections as small as the spacing of the valves will permit, and then closing a section down for a short period (at least five minutes) and re-opening it, and repeating this operation with other sections, until all have been shut down. Another method is to start at the boundaries and work towards the instrument, gradually reducing the size of the district, and as the new boundary valves are closed, the old ones are opened. The method used will depend on the conditions that exist in the district. With either method, the time each shutdown is completed must be noted. It is important that all valve operations should be checked over before leaving the district, to make sure that no valves are left closed.

Locating the Leaks

When the subdivision record has been interpreted we will know the quantity of water each section of the district received. The sections that receive excessive quantities should be carefully gone over and the reason for the large flow ascertained. It is a good idea to have a plumbing inspector make a special examination of the fixtures in all buildings in these areas. If this inspection fails to account for the flow, it is assumed that the cause is underground leakage.

There are a number of methods usually employed to give the exact location of underground leakage. The one most generally used, and the one by which a great majority of leaks are found, is by sounding. There are a number of instruments on the market devised to help in picking up sounds, and those that I have used have proven of great assistance. The procedure is to sound all the valves, hydrants and services in the suspected area, and sometimes it is possible to get closer to the source by driving rods down to the main. It is remarkable what an experienced man can accomplish by sounding. In a great many cases he can not only tell where the leak is, but its nature—whether it is a blown joint, a split main, or a burst service pipe.

There are, however, a number of cases in which the sounds picked up are confusing. Where there are two or more leaks close enough together for the sounds to overlap, it is difficult to isolate the sound from one leak and trace it to its source. Leaks that discharge under water produce a sound that is often misleading. Then there is the abandoned service that has not been properly blanked at the main.

Other methods used in conjunction with sounding include testing the pressure at different points until the point of minimum pressure is located; noting the flow in sewers at the manholes; pounding the road surfaces to endeavor to locate cavities beneath the pavement, and searching in cellars and excavations for dampness.

If the above expedients fail to locate the leak, the primitive of digging is resorted to. It is quite probable that the first hole put down will not be in the right place, but from the conditions that exist at this point, a second hols is usually all that is necessary.

Water appearing any place should be looked on as a possible leak, if the reason for its appearance is not apparent.

Other Duties of Waste Reduction Department

In addition to the work outlined above, it is the duty of the department in charge of waste reduction to attend to all cases of flooding of cellars. The first thing to be done in these cases is to find whether or not the water department is responsible.

When serious breaks occur in the distribution system they usually give plenty of surface indication as to their locality. These are attended to by the trouble department. Bad breaks do occur without giving such indication, however, and these are followed up by the waste-reduction department. In such cases, the department first gets in touch with all the fire halls in the city, each of which has a pressure gauge installed, to find if possible an area in which the pressure has dropped. If no indication is given in this way, men are sent out to go over those parts of the system where it would be possible for the water from such a break to escape without surface indication.

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Send for Bulletins Nos. 17 and 18—Full information on request

FILTER BED MAINTENANCE

A Year's Experience With the Palmer Filter-Bed Agitator

By E. C. GOEHRING, Chemical Engineer

Beaver Valley Water Co., Beaver Falls, Penna.

THE proper maintenance of the sand beds in filters is a problem that is found in most filter plants, and satisfactorily solved in but few. Mudballs, sand coatings, bed shrinkage from side walls, surface cracks and hard spots in the lower bed are evils that practically all operators have to cope with at one time or another.

Many remedies have been proposed in recent years for correcting or minimizing these troubles, but none in the writer's opinion have produced such results as have been obtained by the installation of the recently perfected Palmer "Filter Sweep." This device not only clears up these troubles, but also maintains the beds in as perfect condition as one might wish for. If this statement appears to be a "plug" for the "Filter Sweep" let it be so. The results justify as much.

The Eastvale plant of the Beaver Valley Water Company has six units of one million gallon capacity each, and of rather an unorthodox shape; namely, 25½ by 14 feet. When this plant was designed, in 1922, a wash water rise of 12 to 15 inches was considered adequate. Two reinforced concrete wash water troughs running lengthwise, having a total cross-section area of two square feet, were provided to carry off the wash water coming from a 50,000 gallon tank providing a maximum head of 11 pounds static pressure.

Some Operating Experiences

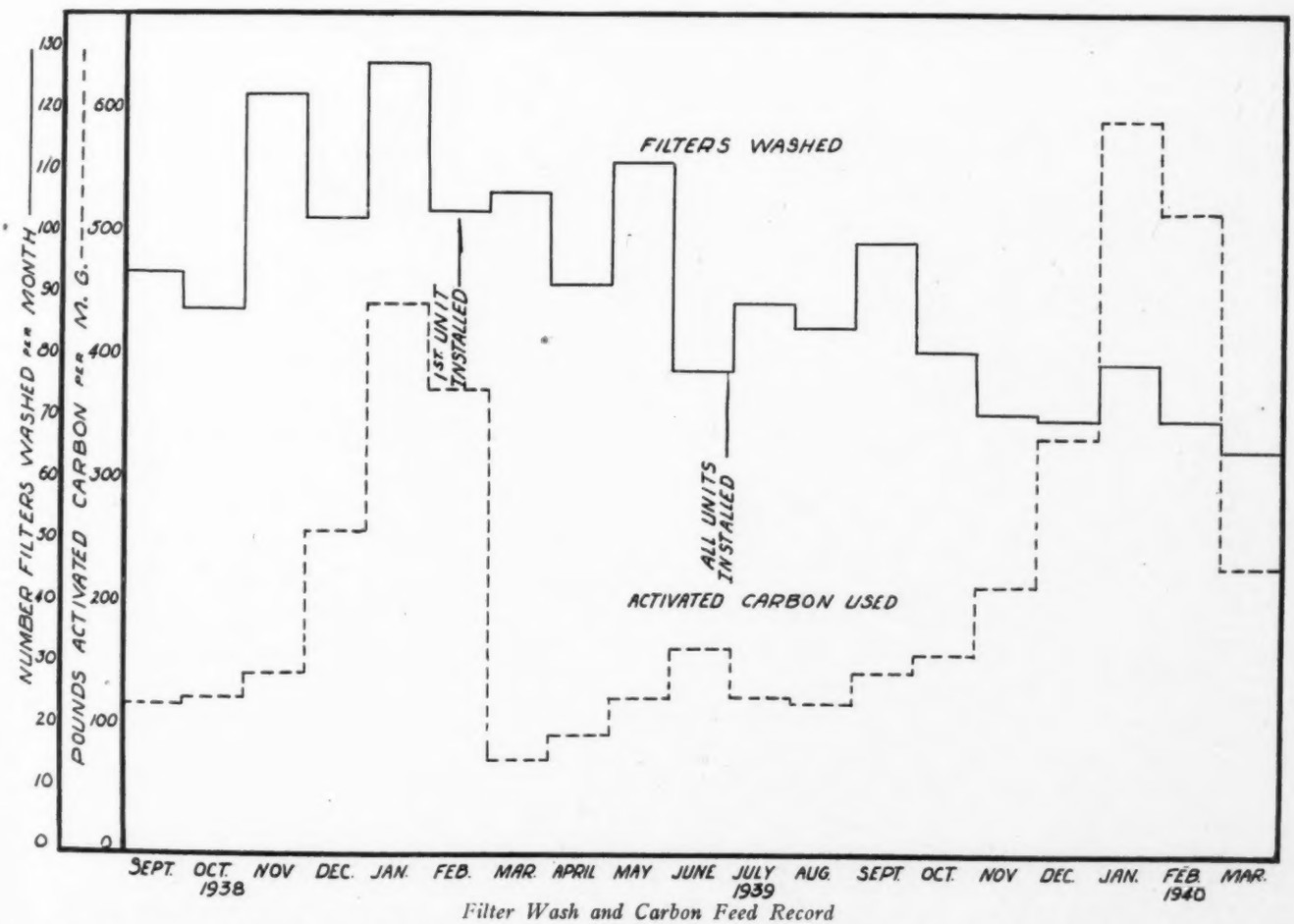
After several years operation, it was found increasingly more difficult to maintain the sand beds in the proper condition, and considerable maintenance had to be used to remove hard spots, to prevent cracks, and sidewall shrinkage. This required passing the sand through a jet washer at least once each year, and thereafter intermittent shoveling and hosing with high pressure nozzles between the scouring jet washes.

In 1936, when higher wash rates and increased sand expansion were being advocated as effective means of sand bed conditioning, a larger wash water tank was installed at a higher elevation to give higher rates of wash. Rates of vertical rise as high as 40 inches per minute were available with the new tank, which has a capacity of 70,000 gallons. While these higher rates helped to keep the hard spots smaller, flooding of the small capacity troughs made our higher rates relatively ineffective.

The Beaver River, which is our source of supply, fluctuates widely in its characteristics, especially in color, taste, and odor. Increased use of activated carbon has been necessary to minimize these tastes and odors. During the past two years abnormally high dosages, ranging to well over 1000 pounds per million gallons, have been required at times.

The increased use of carbon has resulted in increasing the problem of keeping the filters in good condition, and required more frequent washing to prevent passage of the carbon to the clearwell.

The graph, showing the average carbon dosage in pounds per million gallons, indicates clearly the effect on the number of filters washed, particularly before the installation of the Palmer "Filter Sweeps." To anyone who uses carbon, it need not be


NUMBER FILTERS WASHED = MONTH
POUNDS ACTIVATED CARBON = M. G.
FILTERS WASHED
1ST. UNIT INSTALLED
ALL UNITS INSTALLED
ACTIVATED CARBON USED
SEPT. OCT. NOV DEC. JAN. FEB. MAR. APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV DEC. JAN. FEB. MAR.
1938
1939
1940

Filter Wash and Carbon Feed Record

Indicating the effect of the "Filter Sweep" in producing cleaner beds and lengthened hours of filter service between washes. More impressive is the record in the face of heavier carbon loadings since the "Sweeps" were installed.

said that the filter mat becomes unusually sticky and most difficult to remove.

During periods of high colored raw water, coagulation on the acid side is required, and lime is withheld for addition just ahead of the filters for pH adjustment. The combination of high carbon dosages and lime on the filters brought about the appearance of large numbers of black hard balls, which were light enough to remain in the upper six-inch sand strata. Attempts to wash them out by ordinary means failed, and only screening effectively removed them.

Some Filters Overhauled and Experimental "Sweep" Installed in Another

In November and December, 1938, two units (Nos. 1 and 2) were completely overhauled and the sand and gravel replaced with new media. A program was set up, at that time, to replace the beds in all of the units.

In January, 1939, the opportunity presented itself to install one of the new Palmer "Filter Sweeps." This demonstration unit was installed in No. 6, which was the next unit scheduled for replacement.

After about two months' use of this rotary jet sand bed agitator, it was noted that the filter improved to the extent that former hard spots were removed and small surface cracks no longer showed up. The sand began to lose its "sticky feel" and became brighter in color. At the same time, it was noted that No. 1 and 2 units, with the new sand, were becoming infested with "raisin-like" spongy balls of carbon and lime, along with alum floc and algae. The apparent benefit that No. 6 was receiving from the agitator prompted us to install Palmer's "Sweeps" in all of the units. This work was completed in June, 1939.

During the experimentation with the first unit, it was found that better washing could be obtained by increasing the carrying capacity of the wash troughs. We bolted steel plates to the outsides of the concrete troughs, which increased the free-board 6 inches and increased the effective cross-section area of the troughs from a total of 288 square inches to 508 square inches. This increase made it possible to use wash water rises up to 20 inches without flooding the troughs.

It was also noted that a sand expansion of from 10% to 15% was sufficient to make the washing effective when using the "Sweeps," whereas, before, expansion as high as 40% to 50% did nothing more than allow the balls to bob up and down more and to settle deeper in the sand itself.

An almost immediate improvement was noted upon the complete installation of agitators in all units, especially in the new sand units (Nos. 1 and 2), which became entirely cleared of the "raisin-like" balls in a short time. Moreover, these filters have remained as clear as the day the sand was installed over sixteen months ago.

In the four filters with the old sand, the results have also been remarkable in that the former sticky and surface crack conditions have been removed. The sand now is clean and bright. Further replacement with new sand has been indefinitely postponed, resulting in a considerable saving in labor and material cost. Periodic inspections indicate that the beds and the sand are continually improving.

Wash Water Economy

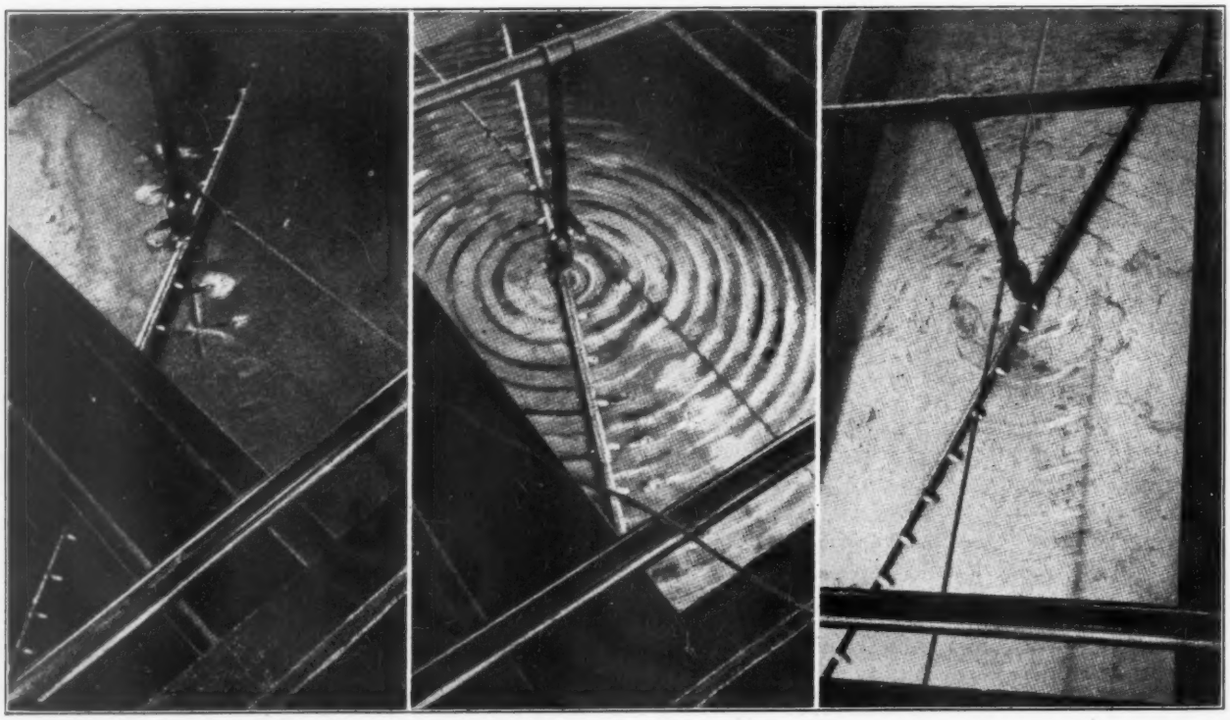
During the past year's experience with the Palmer "Sweeps," no attempt has been made to economize on the amount of water used per filter wash. However, a considerable economy has been effected in that the number of filters washed per month has dropped considerably. The accompanying graph indicates the drop in numbers of filters washed very effectively, in spite of the fact that carbon dosages have been increasingly higher than during a like period prior to the installation of the agitators. The decrease in the number of filters washed is indicative of the increased lengths of runs between washings resulting in a saving in wash water in addition to other advantages from longer filter runs.

A typical example may be cited on the graph. Comparing January, 1939, with January, 1940, indicates a 38% reduction in number of filters washed. This, in spite of increased carbon dosages of 444 pounds per million gallons in January, 1939, to 593 pounds per million gallons in January, 1940.

We have every reason to believe that, inasmuch as this past year has shown a considerable reduction in wash water, the reduction should be increasingly more, in the future, as the past year has been the cleaning period during which the beds have been continuously improving.

The "Filter Sweep"

The pictures of the "Sweep" indicate the nature of the device, which is substantially like the old mechanical rakes, except that instead of wooden or steel teeth, jets of water do a better stirring job. The jets are set in a horizontal arm which revolves like the conventional lawn spray, or the revolving distributor on modern sewage filters only at a much more rapid rate. The nozzle pressure is about 50 pounds per square inch, and, even



The Palmer Filter Bed Agitator and Bed Condition

(1) *Dirty filter drawn down before starting agitator;* (2) *Showing grooves cut by agitator jets;* (3) *After the wash with agitator and up-flow wash, producing only* 10 *to* 15% *bed expansion, and* 3 *to* 4 *minute operation of the agitator.*

with the sand bed not expanded, the jets penetrate as much as four inches into the sand. The pictures show the effectiveness with which the area of the bed is covered by the jets; but only one of the two revolving arms with which each filter is supplied is shown. It is particularly significant to find that the corners of the filters, as well as other segments not directly under the revolving arms, are effectively agitated by jets in the ends of the arms. Our experience has been that the corners on the new sand units are as clean as the remainder of the bed.

Determining Most Effective Use

The operation of the agitators, in conjunction with the usual washing procedure, was modified from time to time to arrive at the procedure which gave the best results.

When a unit is ready to be washed, the filter is drawn down until the water level is even with the jets. The agitator water supply valve is then opened and the agitator made to revolve for one minute. This breaks up the surface mat and makes a heavy slurry of the material usually found on and near the bed surface. This operation has proved a very important part of the procedure. The wash water valve is then opened to give the necessary volume to *just fill* the troughs. The agitator is allowed to rotate for from three to four minutes during the up flow (bottom) washing period before the high pressure supply to the "Sweep" is shut off. We have found that with not more than 10% to 15% expansion, the agitators are completely covered with sand and the jets penetrate into the lower sand layers. Washing is continued until the filter is as clean as experience indicates is consistent with practice for best initial filtration efficiency.

In some cases, especially when the agitators were first installed, it was found almost impossible to "clear up" the filter as long as the agitators were in operation. This definitely indicated the freeing of foreign matter not ordinarily removed in the usual washing procedure. Now, since the filters have become more truly clean, the beds can be washed to a "clear-up" point (meaning clarity of wash-water leaving) with the agitators in operation during the entire washing period. The major objection to this procedure is that when the agitators are shut off *after* the bottom wash-water, upon drawing the filter down, it will be found that the sand will be in a saucer-shaped contour instead of perfectly flat. The writer has observed as much as a six-inch difference of elevation between the sides and the center of the filter bed, enough to stop the agitators when the wash water was shut off before the agitators. This indicates that during the agitation period a very pronounced sand recirculation from the side walls and corners to the center must be taking place in the bed; a feature which commends this device over stationary surface wash jets.

Summary

The past year's experience with this form of surface agitation device indicates to the writer that such troubles, as mudballs, surface cracks, bed shrinkage, hard spots, and sand coatings removable by abrasion, can be effectively removed and the beds maintained in good condition. A definite economy in the use of wash water can be expected after the beds have been cleaned.

The writer's experience with the Palmer "Filter-Sweep" prompted him also to recommend the installation of four units in the Shenango Valley Water Company's filtration plant at Sharon, Pennsylvania, where they are now operating with complete satisfaction also.

DEVICE FOR FEEDING LIME SOLUTION INTO MAINS

By E. T. CRANCH

Manager, New Rochelle Water Co.

New Rochelle, N. Y.

THE New Rochelle Water Company purchases its water from the Croton System of New York City. This is an impounded supply with a normal pH ranging from 6.8 to 7.2.

In order to absorb the free CO_2 and thus reduce the corrosive character of the water The New Rochelle Water Company treats all the water it takes from the Croton Aqueduct with lime to maintain a pH of 8.6. The water is lifted from the Croton Aqueduce by means of pumps located about 15 feet above the water level in the aqueduct. A saturated solution of lime water is continuously fed into the suction line. It was found that lime would build up in the feed piping. By closing the corporation cock all the piping could be easily cleaned except the corporation cock itself, which became badly plugged and it was almost impossible to clean it without shutting down the pumps and losing the suction. As it takes about an hour to prime the suction header after the suction has been lost the station operators never liked to work on the corporation cock.

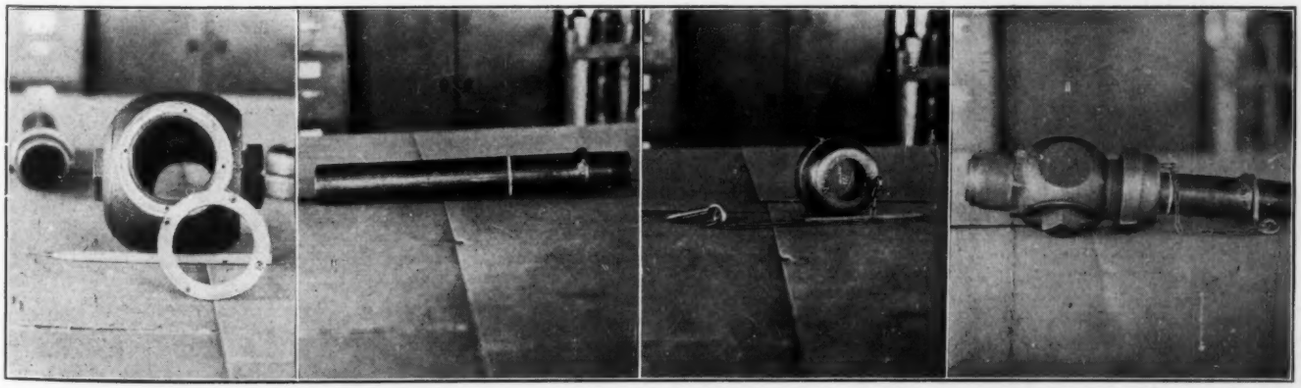
Then it was suggested that a connection to the suction line be made up similar to the usual type of device for feeding chlorine solution. Accordingly Mr. Charles Neydl, who has charge of the Meter Repair Shop, made the device illustrated.

Method of Installation

The device has a tube which slides through a gland and corporation cock and projects into the main. It can easily be withdrawn under pressure, or suction, cleaned and returned.

In order to insert this unit it was necessary to remove the old 1½ inch corporation-cock, drill out the old hole in the 30-inch cast iron suction line to fit a 2-inch corporation-cock and insert the new 2-inch cock. All this was done with a regular Mueller tapping-machine, with the loss of very little suction.

After the tapping machine was carefully centered over the existing 1½-inch corporation-cock the pumps were shut down and the vacuum priming device started. The 1½-inch cock was then removed by use of an extracting plug. Of course the check valve in the tapping machine did not hold against a negative pressure, but this was overcome by placing a board across the open end of the barrel of the tapping machine as soon as the top was removed. In this way so little suction was lost that the priming device had the pumps ready to start again by the time the insertion of the 2-inch corporation-cock was completed.



(1) 2-in. Corporation cock fitted with stuffing box plate exactly to fit 1½-in. Wrought Iron pipe. (2) 1½-in. Wrought Iron pipe with ring welded on it for stop-chain. White painted band indicates correct amount of insertion when feeding lime. (3) 2½-in. Cap drilled exactly to fit 1½-in. Wrought Iron pipe and equipped with rings and stop-chain. (4) Assembled Unit.

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PRODUCTS — Single or Multiple Chemical Feeders for water and sewage plants, the military, and industry; and engineering service on proportioning problems. Feeders are of positive-displacement solution-feed type. For constant rate or proportional feed with mechanical or hydraulic operation. Chemical solutions handled with "See-Thru" transparent plastic reagent end construction include: Sodium or calcium hypo-chlorite, aqua ammonia, soda ash, alum, ferric chloride, ferric sulphate, calgon, sodium aluminate, copper sulphate, sodium hydroxide, dilute acids, etc. Other construction for concentrated Sulphuric acid and hard to handle chemicals. "Name your poison" and we will feed it!!

Chlor-O-Feeders in Water Works Service for Sterilization (Hypo-Chlorinators) — Midget Chlor-O-Feeders (diaphragm or piston type for low or high pressures) for pumped water supplies are the most dependable and least expensive, most accurate and least complicated feeders available for chlorination of up to 1½ million gallons per day. The Chlor-O-Feeder is small, easily and quickly adjustable to various feeding rates; driven by electric motors or belt driven from water pump. Installation is simple with aid of our complete instruction manual.

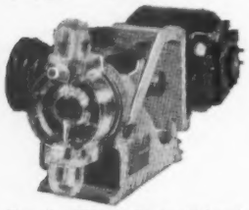


Fig. 1—Heavy Duty Chlor-O-Feeder

Du-Self Chlor-O-Feeder — a complete hypochlorinator for $99, intended for self installation. Do it yourself and save $100! Suitable for water supplies below 25 g.p.m. capacity.

Portable Chlor-O-Feeders — Hydraulically operated or gasoline engine driven. Ready for service at a moment's notice. Feed over 100 lbs. Cl_2 per 24 hours, using Soda Bleach. Ideal for emergency wartime use, as standby for gas chlorination; and chlorination of newly laid mains. Handles pollution problems introduced by broken mains, cross connecting, etc. Every Water Department should have one or more of these units to augment regular chlorinating equipment during extreme demand conditions or in times of disruption of regular water plants by military or other accidental difficulties.

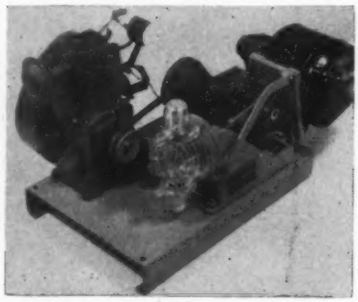


Fig. 2—Portable Chlor-O-Feeder

Proportional Chlor-O-Feeders for Gravity Water Systems — For many conditions, especially in gravity systems from reservoirs, where flow rates vary considerably from hour to hour, it is essential that the Chlor-O-Feeder be controlled by the flow of water so that the amount of solution injected is at all times in proportion. Proportional Chlor-O-Feeder can be mounted on and controlled by any flow-responsive device; standard water meter of any size or type; flow-responsive rotor; venturi tube; orifice plate or even the reciprocating parts of deep-well pumps can be used to "pull the trigger" that sets off the chlorinating discharge. This Chlor-O-Feeder can be operated at any point where the water line can be cut to allow installation of meter. It can be operated entirely by water pressure, so does not require expense of wiring. Operation is simple, not needing expert attendants.

Aqua Ammoniation — Aqua Ammoniation by the "Fume-Proof," "Fool-Proof" %Proportioneers% method enables savings of half your annual ammonia bill and reduces to one-third the initial cost of chloramination apparatus.

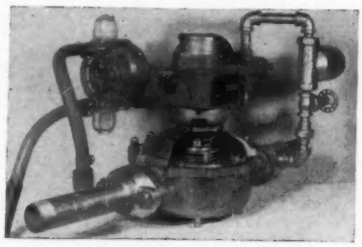


Fig. 3—Meter-Operated Proportional Chlor-O-Feeder

Calgon Feeding and pH Control — pH control by proportioning lime, soda ash, sodium silicate, sulphuric or other acids, is made simple by the use of these flow-proportional chemical feeders. Highly successful installations, designed by leading engineers, are providing permanent relief from plugged and corroded pipe lines. The growing use of Calgon in water works corrosion control finds frequent use of Calgon-Feeder for feeding sodium hexametaphosphate.

Pur-O-Pumper — A "packaged water plant" which can be carried to the job on a light truck, installed either for temporary or semi-permanent use near a stream. Lower the suction hose into the stream, start the gasoline-engine, and the water plant starts operating! The water is treated with coagulant chemicals, soda ash and alum, and chlorine for sterilization as it is pumped into the filter. Pure, clean, SAFE, water is immediately available. We are under contract to the U. S. Navy to supply mobile water purification plants such as previously built for several Armies—friendly European and U. S. A. Full details about these "man-saving" PUR-O-PUMPERS upon request. Used by Waer Works for emergencies and by contractors in field operations.

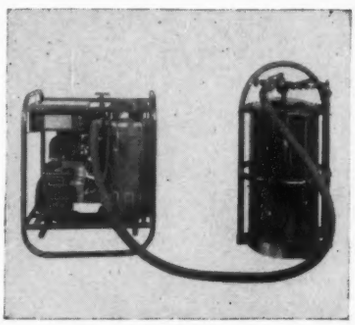


Fig. 4—Pur-O-Pumper

"Burn-Point" Chlorination (Super-Chlorination) — Taste and Odor Control by adding sufficient chlorine to destroy organic substances which cause taste; then dechlorination, by adding sodium bi-sulfite to remove chlorinous tastes but to leave proper residual; answers a serious problem confronting many towns. %Proportioneers% Midget Feeders will handle enough sodium bi-sulfite to dechlorinate the full capacity of a gas chlorinator on water supplies as large as 80 m.g.d. Chlor-O-Feeders will superchlorinate in plants of lesser capacities.

Total Defense for Swim Pools and Foot-Baths — Proper disinfection of swim pools includes not only the maintenance of required chlorine residual in the pool proper, but also disinfecting foot-baths, walkways, pool margins, showers and locker rooms, and feeding of alum coagulant and pH control chemicals. Continuous hypo-chlorination, using %Proportioneers% "Little Red Pump" is the simplest, most dependable and economical method of swim-pool disinfection available. For total war on swim-pool pollution, %Proportioneers% "Two-Time Treatment" is 100% effective and automatic.

"See-Thru" Construction — "See-Thru" Reagent End — of transparent moulded plastic — is standard equipment on %Proportioneers% feeders. Operation of check valves, diaphragm, piston, chemical, etc., bared to constant observation of the operator by %Proportioneer, Inc.% 1940 pioneering in introducing this modern construction for our complete line of pumps.

Fig. 5—"See-Thru" Reagent End

AQUA AMMONIATION

Frequently Advantageous and Economical

By CARL J. LAUTER, Chemical Engineer
Dalecarlia Filter Plant
Washington, D. C.

THE use of ammonia with chlorine as a sterilizing agent has already been exhaustively treated in literature.

Anhydrous ammonia and liquid chlorine became the most widely used products in chloramination. Salts of ammonia, notably the sulfate, were later employed because of the lower cost of ammonia in this form. However, the use of ammonium sulfate often involved considerable handling difficulties. The material, after standing in storage cakes rather hard and unless it is fed soon after receipt, will increase labor costs and will also present feeding difficulties.

Aqua ammonia, which is a 29.4% solution of ammonia gas in water, has only recently come to the front in the chloramine process of water sterilization. Weir of Atlanta has been using it for several years and Atlantic City adopted it in 1939. There seems to be no good reason why its use should not have become more general before this (1940), since its price per pound of ammonia content seems to be the minimum for a good source of ammonia for water works use. Lack of proper feeders for good proportioning of the liquor may have retarded its adoption before this. There are now, however, several very good small feeders on the market which are especially suitable to the character of the solution.

Washington Experiences

At Washington, D. C., chlorination of the city water supply was first initiated in 1923, liquid chlorine being employed. In 1928, prechlorination was added, the advantages becoming at once apparent.

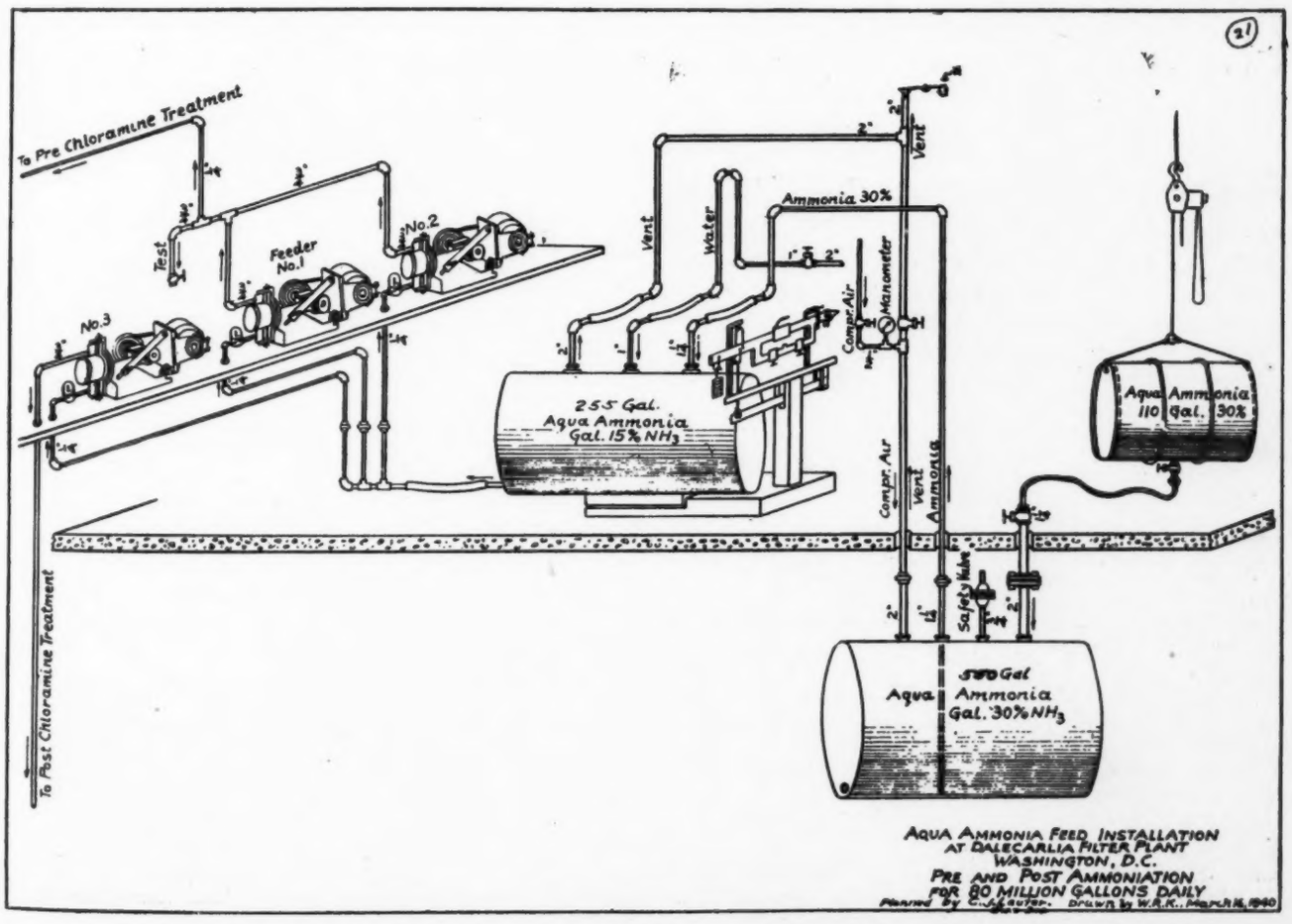
In February, 1933, ammonia with chlorine in the pre-treatment was begun. Immediately there was a betterment in filter effluent, in the condition of the filters, and in the absence of all chlorinous tastes in the water delivered to the city. The coli aerogenes index of the finished water has been practically zero since this date, with chlorine residuals of .15 to .50 ppm.

In 1932, when one-ton containers were substituted for small chlorine cylinders, the cost of chlorine was cut in half, but anhydrous ammonia has remained relatively high in cost; in fact, equal to that of the chlorine when using 5 times as much chlorine as ammonia. Cutting down on ammonia costs, or finding a better source of this material was the next problem.

Aqua Ammonia Proves Solution

In 1938, it was finally decided to adopt aqua ammonia, due to its lower cost, and to feed it with the chlorine not only to the pre-application point but also with the post treatment, where only very small amounts of both chlorine and ammonia are needed. Since January 1, 1940, the Dalecarlia plant has been operating continuously on this basis. All aqua ammonia to date has been procured in 110-gallon drums holding 750 pounds of 29.4% NH_3 and now costing $.0225 per pound, equivalent to $.075 on the anhydrous basis. This price is for carload lots of 45 drums per minimum car at the filter plant rail siding.

Feeding equipment at Dalecarlia consists of three heavy duty diaphragm type proportioning pumps (see sketch) which can be readily and accurately adjusted to the demands and to keep step with the variation of the chlorine dosages, feeding as high



Sketch Showing Details of Arrangement of Feeders, Solution Tank and Aqua-Storage

as 48 pounds of 15% liquid per hour from one machine, or down to infinitesimal amounts on the post treatment. The 29.4% ammonia is discharged from the 110-gallon drums from a point outdoors into a 550-gallon receiving tank located in the basement of the plant to which it flows by gravity.

Simplicity of Operations

From the receiving drums the ammonia liquqor is forced by air pressure to the operating floor above and discharged into a 225-gallon dispensing tank which is placed horizontally on a platform scale (see layout sketch). The piping is of ordinary black iron fitted with black-iron ammonia valves (copper or brass must be avoided in the system). The 225-gallon tank is pumped half full of the 29.4% ammonia liquor, this being determined by the scale weight, after which an equal weight of water is added to bring its strength down to 15% NH_3. Since the ammonia pumped weighs 1.34 pounds less per gallon than the water, which enters through the top of the tank, the mixing is thorough. This diluting and dispensing tank has a capacity of 2100 pounds of the 15% mixture, which is immediately ready for pumping. Exact weights of both the ammonia and water can be easily transferred, as all valves are conveniently arranged in close proximity to the scale beam. The entire system is vented to the outside, and is under a slight back pressure. This makes possible all handling and dilution without any escape of ammonia inside of the building. Dilution to 15% results in a better and less volatile solution for the feeders and also gives better amounts for hourly weight checking which, however, is not continually necessary due to the exact measuring which we have found possible with the diaphragm pump feders. Separate pump suction lines are provided for each feeder and sight glasses give a definite indication of feeding rates at all times.

Consideration is now being given to the installation of a 12,000-gallon storage tank at a rail siding so that the 29.4% aqua ammonia may be delivered in tank cars at a reduction in price over that charged for the 110-gallon drums now used.

The 15% solution is fed to both pre and post-chlorination points. On the pre-position it is introduced into the water coming from the settling basins and going to the filters just prior to the chlorine, while on the post treatment both ammonia and chlorine are added at the same point, discharging direct into the filter effluent at atmospheric pressure.

During the last fiscal years (before aqua), the annual consumption of anhydrous ammonia at Dalecarlia was 21,000 pounds, fluctuating from 25 to 100 pounds daily. All of this was added to the prechlorination point. During the summer months when demands for 4 or 5 pounds per hour existed, there was always considerable refrigeration with three 150-pound anhydrous cylinders and it was practically impossible to feed these amounts with any degree of regularity. Heating of the cylinder was necessary and this practice leads to fluctuations in feed rates. Uniform rates of delivery were practically impossible.

At the McMillan slow sand plant, the consumption for the same period was 3000 pounds of anhydrous, during a 5 month period.

Advantages Accruing

The estimated consumption of ammonia for the coming year is around 30,000 pounds as NH_3 or about 90,000 pounds of 29.4% aqua ammonia. With this amount, net savings should be well over 50% of present costs of anhydrous ammonia NH_3, and will give additional advantages as follows:

(a) There will be no refrigeration trouble, and no heating of cylinders and hazards involved in the handling of anhydrous products.

(b) Feeding requirements can be more easily regulated, allowing minute or large dosages to be maintained as desired without fluctuation.

(c) With aqua, it is easier to arrange feeding schedules and operators are not required to handle heavy tanks at inopportune times.

Aqua ammonia should afford a most practicable and economical source of NH_3 for any plant operator who is interested in chemical savings and efficient application of ammonia.

MUD-BALL AND HARD-SPOT BREAKER

By HOMER W. SCHUMPERT

Superintendent of Water, Light and Sewage, Newberry, S. C.

Like many other plants, our filtration plant at Newberry has been troubled with mud-balls and hard-spots in the sand beds.

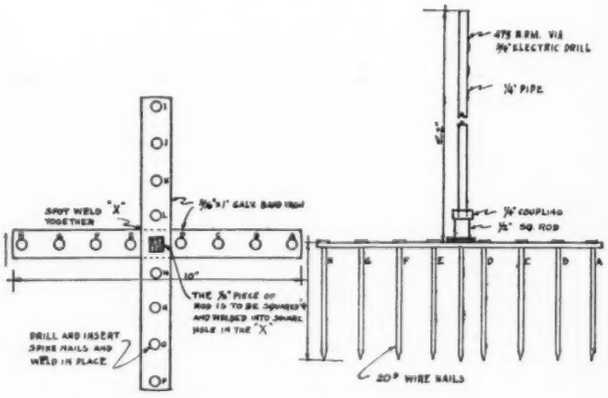
After trying many schemes and devices, that to be described seems to be of sufficient value to justify its publication.

The "Mud-Ball Breaker," as we call it, is here sketched. It is made from two 10-in. pieces of cross-arm bracing, for electric-line poles, welded in the form of a cross and attached to a shaft of ¼-in. steel pipe. The "tool" is turned by a light weight hand motor such as is used for electric hand-drills.

Through the pieces of bracing (1 in. wide by 10 in. long by 3/16 in. thick) are drilled holes to take 20-penny nails and a square hole (½ by 1.2 inches) is cut at the center of the cross (see sketch). The nails are welded in at their heads and the strips of bracing are spot-welded together at the center. A 2-in. piece of ½-in. steel rod is squared at the end and welded into the square center hole. A coupling and reducer connect the rod and the shaft of ¼-in. pipe. This shaft, 2 ft. long, fits into the chuck of the standard ¾-in. electric hand-drill which has a free-speed of 475 r.p.m.

Using the Filter Wash Tool

The water level is lowered in the filter until only 1 or 2 in. stands above the filter bed. Then the operator plugs in the cord of his tool (drill) and climbs down into the filter troughs. He starts the tool rotating at the 475 r.p.m. speed and proceeds to attack the mud-spots with it for about 6 minutes, employing a churning (up and down) motion of the whirling head. Then the filter is washed as usual.


475 R.P.M. VIA ¾" ELECTRIC DRILL
¼" PIPE
¼" COUPLING
½" SQ. ROD
SPOT WELD "X" TOGETHER
10"
THE ½" PIECE OF ROD IS TO BE SQUARED & AND WELDED INTO SQUARE HOLE IN THE "X"
DRILL AND INSERT SPIKE NAILS AND WELD IN PLACE
20d WIRE NAILS

Details of the Mud-Ball Breaker

We tried experiments thinking it possible to improve this device, but in the end we believe the sketched tool, as simple as it is, does the best job without the "improvements." When the spinning cross arms strike a wall the tool merely bounds away without damage. The whole assembly is light, inexpensive, and (most important) it does the job.

[Mr. Schumpert comments by letter: "If you do not believe that the job is easily and effectively done, then just try it yourself."—Ed.]

WILSON CHEMICAL FEEDERS, INC.

Manufacturers of PULSAFEEDERS for Hypo-Chlorination of Water
BUFFALO, NEW YORK

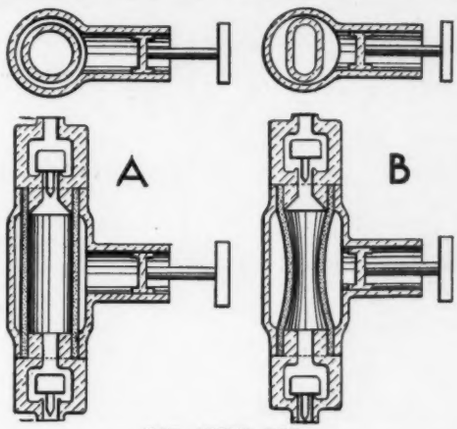
Operation of the PULSAFEEDER

The Wilson PULSAFEEDER combines the advantages of both piston and diaphragm hypo-chlorinators, at the same time avoiding the disadvantages of each type.

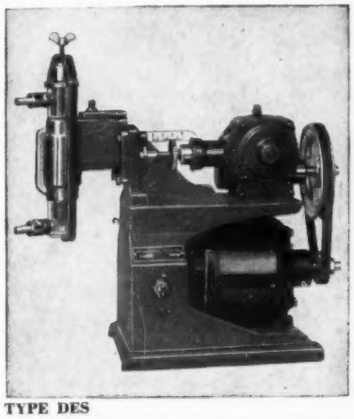
The diagrams A and B at the right, illustrate the extreme simplicity of the PULSAFEEDER operation.

The PULSAFEEDER consists primarily of a piston operating in a sealed chamber of inert, uncompressible liquid, within which is contained a flexible "pulsating tube." This tube is compressed by the piston stroke thus forcing an accurately predetermined amount of the hypochlorite or other desired solution through the feeder. The interior of this "pulsating tube" is made of materials unaffected by the chemical used. As the pressure exerted on the tube is balanced by an equal pressure within the tube, it does not require any fabric or other reinforcing.

Volume control is provided by a micrometric stroke length control, the average size PULSAFEEDER having over one thousand settings with an increment of adjustment of .0277 of a millimeter. Sizes range in capacity from a minimum of 1 cc to 75 gal. per hour.



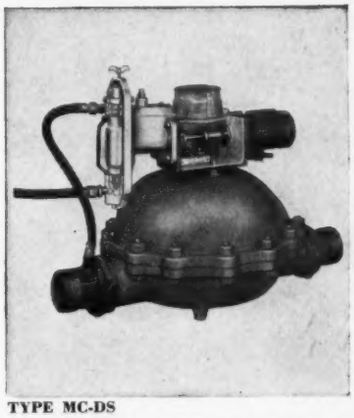
PAT. APPLD. FOR



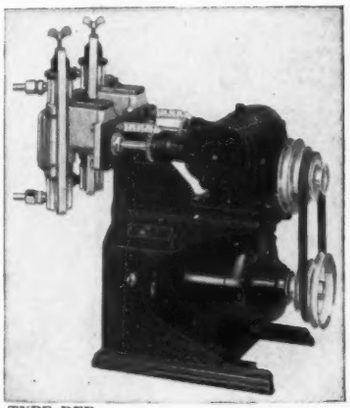
TYPE DES

Types of PULSAFEEDERS

The various types use electric motor, gasoline engine or water motor drives, and are controlled by water meters of all types. Semi-automatic, manually adjustable, and fully automatic hypo-chlorinators are available. Single, duplex, triplex and quadruplex manually controlled feeders are pictured at the left; full automatics, as shown at the right, can be had in multi-feeders for two or more chemical solutions. There is a PULSAFEEDER to give perfect results, whether the installation is a gravity water supply, pumped supply, or a swimming pool.



TYPE MC-DS



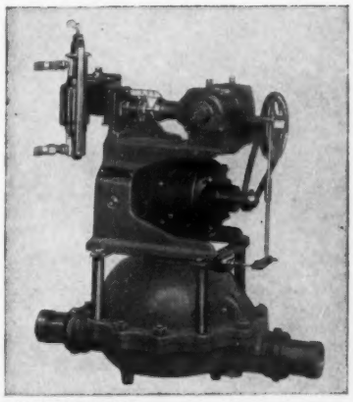
TYPE DED

Manually Controlled PULSAFEEDERS

Type DES: For use with pumped water supplies. Automatic proportioner when cross-connected to throw-out switch of water pump. Bulletin DE-201.
Type DBS: Same as DES arranged for belt drive. Bulletin DB-16.

Type DED: Duplex feeder similar to DES ordinarily used with ammonia and chlorine solutions for chloramination. Each pump separately adjustable. Bulletin DE-202.

Type DET (Triplex), DEQ (Quadruplex): All purpose swimming pool chemical feeder. Feeds chlorine, the sterilizer; alum the coagulant; soda ash, the pH adjuster; and ammonia for chloramination. Each unit separately adjustable. Bulletin DE-203.



TYPE DES-41-H

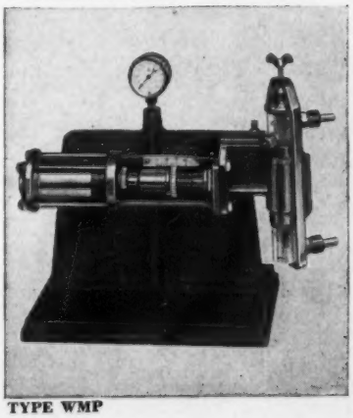
TYPES DET, DEQ

Automatic PULSAFEEDERS

Type MCDS: Fully automatic hypo-chlorinator for gravity water supplies. Water motor powered and meter controlled. Guaranteed as accurate as the meter. Bulletin DE-205.

Type DES-41H: Fully automatic proportioning type. Electric motor drive and control by any mechanical water meter. Bulletin DE-206.

Type WMP: For automatic or semi-automatic use. Water motor drive. Bulletin DE-204.



TYPE WMP

GRAVER TANK & MFG. CO., INC.

EAST CHICAGO, IND.

NEW YORK CATASAUQUA, PA. CHICAGO TULSA

GRAVER BUILDS

WATER SOFTENERS; FILTRATION SYSTEMS; CLARIFIERS; STEEL STORAGE TANKS; VAPOR CONSERVATION SYSTEMS; FABRICATED STEEL AND NON-CORROSIVE COMPOSITE PLATE.

A Partial List of Graver Products

AERATORS
- Coke Tray
- Ceramic Raschig Ring
- Pressure Diffuser Type
- Baffle Plate Type
- Cascade Type
- Tray Type
- Spray Type

CHEMICAL FEEDERS
- Pressure Type
- Gravity Type
- Dry Type
- Solution Type
- Chemical Mixing Equipment
- Lime and Soda
- Alum
- Ferrisul
- Phosphate
- Sodium Sulfate
- Sodium Sulphite
- Soda Ash
- Lime
- Calgon

CLARIFIERS
- Sugar Juice
- Liquid Food Products
- Municipal Water Supply
- Boiler Water Supply
- Paper Mill Cooking Liquors
- Paper Mill Waste Water
- Industrial Waste Water
- Sewage

CHLORINATORS
- Gas Type
- Solution Type
- Electric

FILTERS—MUNICIPAL DOMESTIC, INDUSTRIAL
- Taste and Odor Removal
- Water
- Sand and Gravel
- Iron Removal
- Condensate
- Boiler Feed Water
- Oil Removal
- Swimming Pool Water

FILTERING—MUNICIPAL, DOMESTIC, INDUSTRIAL
- Water
- Chemical Solutions
- Precipitates
- Food Products Precipitates
- Muds
- Sugar Mill Muds
- Paper Mill Wastes
- Municipal Water Supplies
- Domestic Water Supplies
- Boiler Water
- Sewage

FILTERING MATERIAL
- Filter Sand
- Gravel
- Crushed Quartz
- Silica Sand
- Carbonaceous and Non-Silicious
- Activated Carbon

GENERAL WATER CONDITIONING
- Municipal
- Industrial
- Railway
- Domestic
- Hospitals
- Hotels
- Power Plants

HEATERS
- Feed Water Open Type
- Feed Water Spray Type
- Deaerating Tray Type
- Deaerating Spray Type
- Closed Tubular Type

PROPORTIONING EQUIPMENT
- Meter Type
- Shunt Type
- Gravity Type
- Orifice Type
- Continuous Displacement Type

SWIMMING POOL EQUIPMENT
- Swimming Pool Water Filters
- Chlorinators
- Coagulant Feeders
- Hair Strainers
- Pool Fittings
- Rate of Flow Indicators
- Pool Cleaners
- Pumps and Motors
- Underwater Lights
- Alkalinity Feeders
- Testing Equipment
- Ammoniators
- Ladders
- Diving Boards
- Diving Towers
- Life Guard Equipment
- Foot Baths
- Heaters
- Temperature Regulators
- Steel Swimming Pools

THICKENERS
- Corn Products
- Soy Bean Products
- Pulp and Paper Mills
- Sludge
- Sewage
- Chemical Precipitates
- Reclamation of Minerals

VENT CONDENSERS
- Straight Tube Type
- Bent Tube Type

WATER SOFTENERS—MUNICIPAL, DOMESTIC, INDUSTRIAL
- Lime and Soda (Cold or Hot Process)
- Combination Lime and Soda Acid Zeolite
- Synthetic Zeolite
- Natural Greensand Zeolite
- Processed Greensand Zeolite
- Carbonaceous Zeolite
- Acid and Caustic Regenerated
- Acid and Sodium Chloride Regenerated
- Lime and Soda Sludge Filtration

GRAVER service includes design, engineering, fabrication, erection, and full instructions for the operation of the products listed above.

Other GRAVER products, shop-built or field erected, include steel storage tanks, vapor conservation equipment, pressure vessels, stills, condensers, stainless and composite metal equipment, etc.

GRAVER also maintains a complete construction division, fully equipped with tools, erecting equipment, and experienced personnel for the erection of process equipment and other industrial facilities.

GRAVER engineers may be consulted without obligation, concerning specific problems.

GRAVER CLARIFIERS WATER CONDITIONERS CHEMICAL PROCESS EQUIPMENT

PRACTICAL ASPECTS OF POROUS PLATE FILTER BOTTOMS

Based on Experiences at Larchmont, N. Y.

By HENRY T. HOTCHKISS, Supervising Chemist
Department of Water and Sewage, Larchmont, New York

IT IS obvious that in passing down through a filter bed, water goes from zone to zone of varying function. The sand-gravel interface has received notice in connection with both sand support and wash water distribution. Such functional analysis is necessary in order to understand the losses of effectiveness which may arise from disruption in any of these zones and so that corrective measures may be taken.

In an otherwise quite excellent outline[1] there is found a general disclaimer for faulty filter design in the following statement: *"Sometimes trouble occurs in a filter bed due to local displacement of gravel. It may be that some of the large gravel has been forced upward through the fine gravel, or the fine gravel may be ridged or mounded in places. Unless the causes for such conditions are understood, the general movement may be wrongly attributed to faulty design or construction of the filter bottom."*

This, the writer believes, should not be accepted as a dogmatic statement that filter design has been perfected or standardized, but rather as an admission that improvements are needed.

Again a statement[2] is made that *"Another drawback is that although we may say filters are poorly designed, we do not have good proof of the assertion.*

"Perhaps most of us believe we know a better filter design, yet no one has produced a filter bottom in which filter beds handling various types of water have all remained in good condition. Either the ideal design has not been found or there are certain inherent weaknesses which cannot be remedied by any design of the bottom. The latter is believed to be the reason."

This statement should spur on investigations seeking to perfect both design and operation.

Bed Surface the "Tell-Tale"

The surface layer gives some indication of the state of affairs in the zones below. Mounds and craters are generally symptoms of internal troubles. Smaller mudballs may be localized at or near the surface, but hard spots and cracks due to bed shrinkage result from dirty sand or upset gravel. Surface washing systems, when provided, give the operator a valuable tool for improving sand conditions. They cannot, however, be expected to correct deep bed disruptions. A clever operator, even without use of surface wash, can, by the use of rake and water jet, "iron out" these surface blemishes. This, however, does not correct the underlying flaws. These can only be cured by a major operation.

There is, unfortunately, no influence acting during the backwashing operation to restore, once disturbed gravel to its original graded position. This is so because those forces which move the gravel are all localized and due to high velocities created by various conditions over which the operator may or may not have control. Studies indicate that at times, when wash water is first introduced—and even when the rate-of-rise is still low—there is a tendency for the sand to expand *from the bottom* as the sand mass is lifted. Then a weakening takes place, at one or more points. Finally gravity prevails and the less dense fluid (sand-water mixture) gushes up through. The velocities of these vertical jets, coming from deep down, are of gravel moving magnitude. This may and does happen before a normal maximum rate-of-wash is reached. The fewer the points of breakthrough, the more violent is the local action. [Filter beds containing air removed from the water during filtration have been known to "blow-up" when cracking the wash valve with the net result of an inverted gravel bed and trouble.—Ed.]

In recent years, the importance of the sand-gravel junction has been more fully appreciated.[3] In this zone the wash water is finally distributed to the sand. The loss-of-head throughout the interface must be of constant magnitude if even velocity distribution is to be attained. Here, however, is the most unstable portion of the gravel, because the gravel approaches sand grain dimensions.

Why the Gravel Bed?

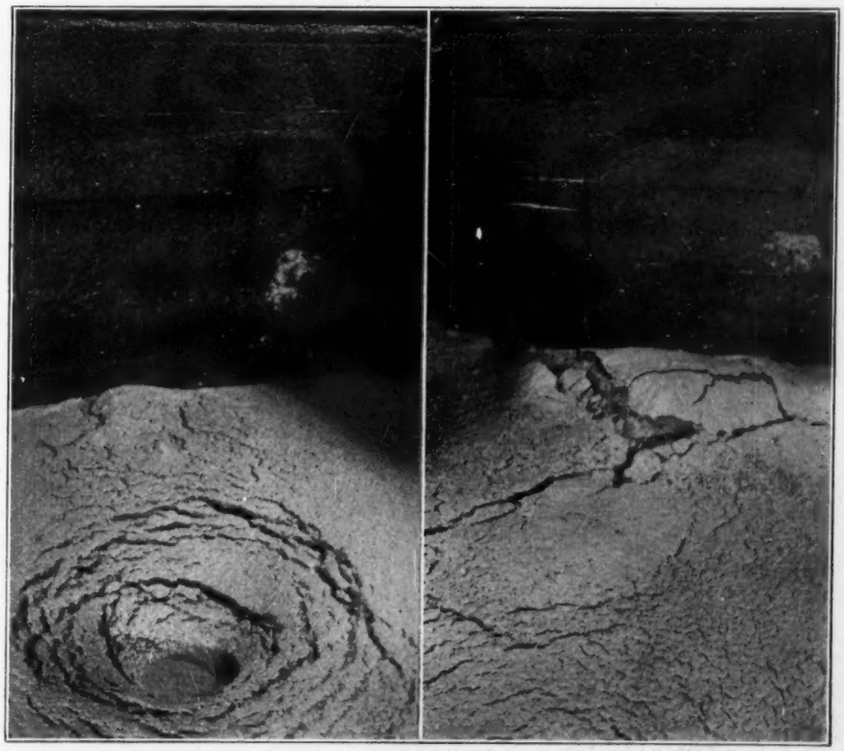
Sand of good quality and proper size is provided to act as a straining medium, primarily for removing the suspended matter present in the applied water. In rapid mechanical sand filters the action is physical in nature.

As for the gravel, it does not seem possible to build such a substantial case of necessity. As a matter of fact, from what has been outlined previously, the evidence indicates that a good case exists for eliminating gravel from filter design. This can be done if a method of supporting the sand and distributing the wash water can be provided. The proposals of H. N. Jenks[4] and especially the studies of Professor T. R. Camp have led to the production of manufactured porous plates for this purpose. Their use appears to be a cure for chronic filter illness due to deep bed gravel upheavals.

The Porous Plate Bottom

Any discussion of the merits of porous plates over conventional under-drain systems has been purposely omitted since this topic has already been given some attention.[5]

It must be admitted that there is the likelihood of fine grained

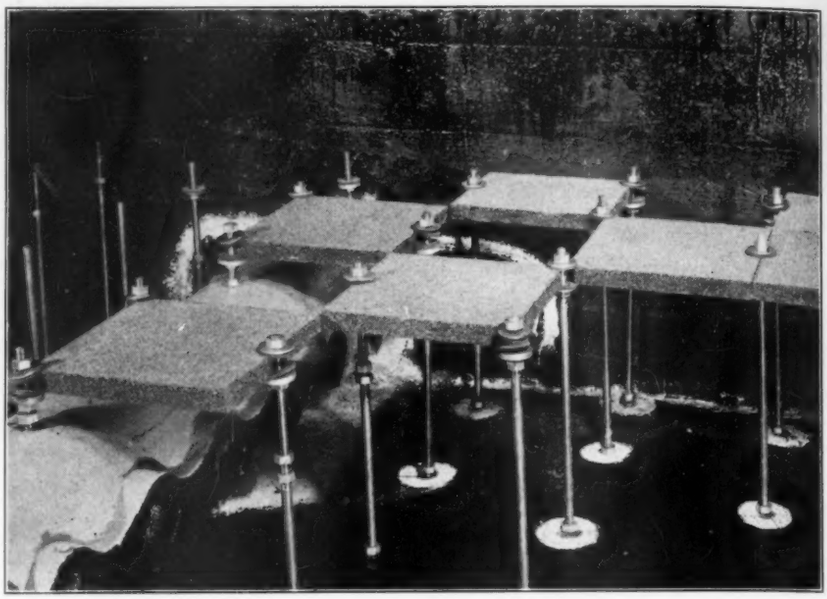


Some Cause for Concern

Filter Bed Conditions at Larchmont Which Aroused Our Interest in the Possibilities of Improved Design and Eventually the Installation of Porous Plate False Bottoms and Elimination of Trouble-making Gravel.

plate clogging; but because of the comparatively low initial head loss through the plates and because of the equalizing factor which exists as the less resistant pores become constricted, considerable leeway is provided before cleaning operations are required. Possibly, routine treatment of the plates with dilute acid at one or two year intervals will be found desirable. Certainly, the characteristics of the applied water should be scrutinized carefully if calcium carbonate or other deposition is probable, so that suitable provisions may be made for protecting the plates.

Since the advent of the porous plate filter bottom there has been a conservative desire to know, in advance, just what the life of the plates will be. There is no question concerning their mechanical strength. Nor is there doubt of their ability to withstand the chemicals normally present in water and sewage, or even acid solutions of considerable strength. The question raised is a matter of performance. Will clogging take place at a rate which will nullify their usefulness? Subsequqent to the provision of automatic rate-of-wash control it has been possible to secure comparative loss-of-head data.



Construction of Porous Plate Filter Bottoms at Larchmont, N. Y.
The Norton plates (12"x12") are installed with three point support, making for ease in levelling and alignment. The rods, washers and bolts are of "Everdur" bronze. The plates form a false bottom above the original manifold.

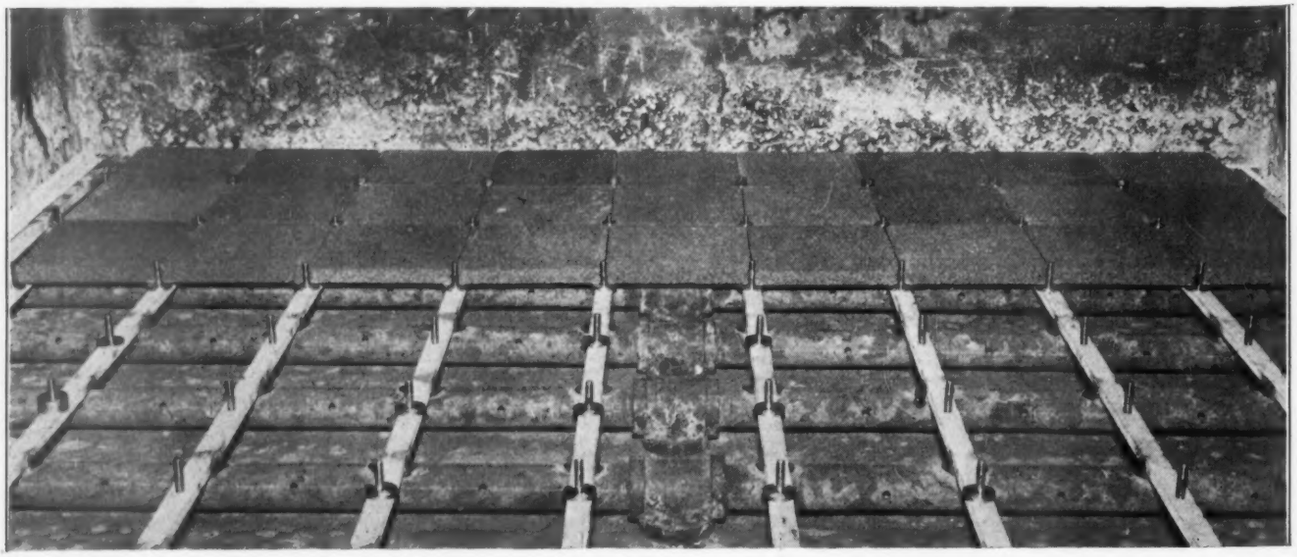
Larchmont Experiences

The original filter unit, equipped with a porous plate bottom and placed in service July, 1939, in our plant, as recounted in this magazine,[5] has been in continuous use. This was equipped with piezometer tubes just above and below the plates in order to follow any changes in the hydraulic characteristics of the plates. Readings taken indicate, as anticipated, an increase in loss-of-head. An intermediate interval was also observed when the loss decreased for a time. The net result by February 21, 1941, was a total head loss through the plates of 24 inches of water. This was with a wash rate of 16.1 gals. per sq. ft. per min. (approx. 26 inch rise per min.). This head loss is not considered high. New plates showed an initial loss of four inches of water under similar condition. The loss during filtering at design ratings continues very low.

In order to provide some indication of the effectiveness of rinsing the plates with dilute acid, the unit was cut out of service on February 21st. The following procedure was used to introduce sulfuric acid, using fittings provided for the purpose in the original installation.

A syphon line, of common garden hose, was led from a crock on the filter gallery floor to the underdrain manifold. Water flowed into the crock and to the filter bottom by way of the syphon at about five gallons per min. The 66° Be. technical sulfuric acid was run into the crock at a slow rate by means of a glass funnel so that within an hour's time 81 lbs. had been used. A solution of 1¾ per cent by weight, on the basis of the acid used, was thus made and provided about 300 gals. of dilute acid. The level of water in the filter, which had previously been drawn down just to the sand, rose slowly. The water flowing through the hose was permitted to force the acid slowly up through the plates and sand for an hour.

Thereafter, wash water was introduced at a slow rate for an additional half-hour, when the water level had reached to within a foot of the lip of the wash gutters. Then the wash was continued at normal rate, utilizing 30,000 gals. to sweep out the residual acid and loosened solid. Water was then filtered to waste until the pH had increased to the point where the filtrate had become alkaline to methyl orange. The loss-of-head through the plates was measured during the wash. It was found that this mild treatment, over a period of two and one-half hours only,



Construction of Power Plate Bottoms of the Ford Motor Co.'s Plant at Flat Rock, Mich.
The "Aloxite" 12"x12" plates, resting on steel bars welded to the old laterals drilled along their sides, are held in place with studs, nuts and washers of phosphor-bronze.

had reduced the loss of head during the 26 inch wash rate to 12 inches of water, or *just one-half*. The cost was about five dollars.

An Air-Water Brush

The following interesting disclosure may possibly be premature, but we shall take the chance in relating it at this time. For some time since the initial plate installation in 1939, there has been the temptation to utilize the porous plate botom as an air diffusing medium in order to obtain the scrubbing air-wash effect, particularly since the merits of this form of agitation have not been seriously discredited. It happened that the installation of rate-of-wash control in conjunction with a new steel all-welded wash water tank made it possible to introduce air along with the wash-water; and, moreover, without any cost for equipment or power. This was done by applying the aspirator principle.

A tap was inserted in the upper leg of a 12-inch tee having a 10-inch side connection to the rate-of-wash controller set between the tee and the wash water storage tank. The upper leg is normally valved off, being connected to the tank to by-pass the controller if need be at any time. The lower leg is joined to the 12-inch wash water line leading to the filters. The center line of the tee stands about 13 feet above the sand surface. By cracking the valve at the tap as the wash valve opens, adequate volumes of air are inspirated and carried by the wash water to the plates. In this way very good air distribution is secured over about two-thirds of the area of the bottom. Varying degrees of violence of sand agitation and circulation, depending upon the volume of air admitted, have been secured. By shutting down the air before the end of the wash, as is usual, the air is swept from the system by the finishing water wash.

Thus the entire sand mass may be subjected to a thorough going-over without auxiliary equipment. This novel water-air wash procedure is possible with the rigid sand supporting medium, and absence of gravel.

Adequate descriptions of porous plate installations have already appeared.[6] Certain refinements of detail and construction features which have been incorporated in the three new units provided at the Larchmont, N. Y., plant are being covered in an article to appear in "Public Works."

When the water level is drawn down below the sand in the three new units, the sand surface is almost carpet smooth. The accompanying picture, in which a fairly heavy blanket of alum floc and activated carbon has been retained on the sand, is hardly a substitute for visual inspection. From an operating angle the results with the first bottom of porous plates have been very gratifying.

References

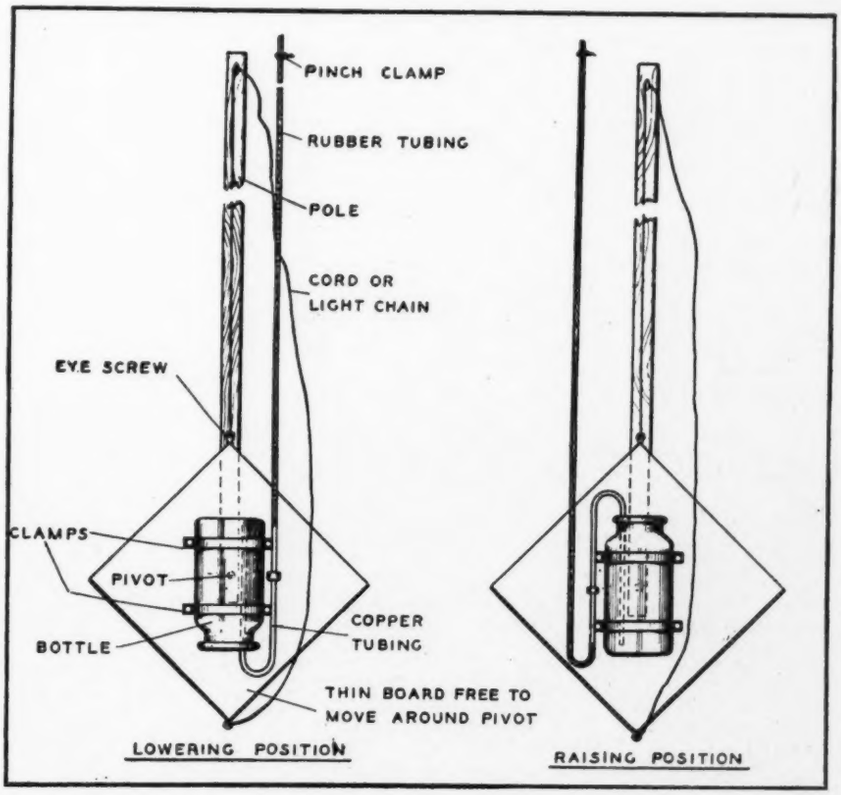
[1]Manual Eng. Practice No. 19 Am. Soc. C. E. (1940).
[2]J. R. Baylis, Water Wks. Eng. **93**, 1432 (1940).
[3]T. R. Camp, J. New England Water Wks. Assn. **49**, 1 (1935).
[4]J. Am. Water Wks. Assn. **16**, 542 (1926).
[5]H. T. Hotchkiss, Water Wks. & Sewerage **86**, 442 (1939).
[6]H. T. Hotchkiss, Water Wks. & Sewerage **86**, 442 (1939).
[6]H. T. Hotchkiss, Water Wks. & Sewerage **92**, 1426 (1939).
[6]L. R. Stevens, Water Wks. & Sewerage **87**, 111 (1940).

APPARATUS FOR COLLECTING FLOCCULATED SAMPLES*

THE apparatus shown on the accompanying sketch consists of a wide mouth bottle clamped to a thin board, which in turn is attached to a pole of suitable length. The board is free to rotate on the center pivot and may be turned by the string or light chain attached to the two opposite corners. The bottle may be vented through tubing which extends above the liquid surface.

When the bottle is lowered in inverted position, the pinch clamp on the vent line is closed. When the desired sampling level is reached, the pinch clamp is released, so that the floc containing liquid slowly enters the bottle as the air is released. When the bottle is full it is rotated and then raised to upright position with the pull chain.

Through use of this apparatus, flocculated samples from any liquid depth may be collected. The breaking up of flocs, such as occurs when samples are pumped or taken by means of a small mouthed bottle, is avoided.



Acknowledgment

This device employed in studies made by the authors at Ypsilanti, Mich., was perfected by Mr. Geo. Darby, Director of the Westport Laboratories of the Dorr Company. It is a modification of a somewhat similar device earlier developed at the Howard Bend Purification Plant at St. Louis, Mo.

*Contributed by A. J. Fischer and A. Hillman, The Dorr Co., New York City. Printed in Water Works and Sewerage for April, 1940.

CONTROL OF ALGAE

By FRANK E. HALE, Ph.D.

Director of Laboratories, Dept .of Water Supply, New York City.

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into arms by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by the barrel arrangement shown. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sets on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4 . 5H_2O$) Per 100 lbs. solution	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys many *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500..	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. Cyclotella has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA*

Organisms—Odor:	Copper Sulphate[1] Parts per million	Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Aromatic, geranium, fishy			
Cyclotella†‡			1.0
Faintly aromatic			
Diatoma†			
Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion			
Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡	0.36*-0.50*	3.0-4.2	1.0
Earthy			
Stephanodiscus	0.33	2.8	
Tabellaria‡	0.12*-0.50*	1.0-4.2	0.5*-1.0
Aromatic, geranium, fishy			
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡			0.5*-1.0
Grassy, nasturtium, fishy			
Draparnaldia	0.33	2.8	
Eudorina	10.00	83.0	
Faintly fishy			
Entomophora	0.50	4.2	
Glœocystis			
Offensive			
Hydrodictyon†	0.10	0.08	
Very offensive			
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina	10.00	83.0	
Faintly fishy			
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡	0.25	2.1	0.3*-1.0
Fishy			
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡	0.12*	1.0	0.5*-1.0
Moldy, grassy, vile			
Aphanizomenon‡	0.12-0.50*	1.0-4.2	0.5*-1.0*
Moldy, grassy, vile			
Clathrocystis	0.12*-0.25*	1.0-2.1	0.5*-1.0
Sweet grassy, vile			
Cœlosphærium‡	0.20*-0.33	1.7-2.8	0.5*-1.0
Sweet grassy			
Cylindrospermum	0.12	1.0	
Grassy			
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia			
Moldy, grassy			
Protozoa:			
Bursaria			
Irish moss, salt marsh, fishy			
Ceratium†‡	0.33	2.8	0.3*-1.0
Fishy, vile, (rusty brown color)			
Chlamydomonas	0.50-1.0	4.2-8.3	
Cryptomonas	0.50	4.2	
Candied violets			
Dinobryon‡	0.18*	1.5	0.3*-1.0
Aromatic, violets, fishy			
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium	0.50*	4.2	
Fishy			
Mallomonas	0.50	4.2	
Aromatic, violets, fishy			
Peridinium	0.50*-2.00	4.2-16.6	
Fishy, like clam-shells			
Synura‡	0.12*-0.25	1.0-2.1	0.3*-1.0
Cucumber, muskmelon, fishy, bitter taste			
Uroglena‡	0.05*-0.20*	0.4-1.6	0.3*-1.0
Fishy, oily, cod-liver oil taste			
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa†	5.00	41.5	
Very offensive decayed			
Cladothrix	0.20	1.7	
Crenothrix†‡	0.33 -0.5*	2.8-4.2	0.5*
Very offensive decayed, medicinal with chlorine			
Leptothrix†			
Sphaerotilis, natans†	0.40	3.3	
Very offensive decayed			
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis†	0.10 -0.18*	0.8-1.5	
Objectionable			
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

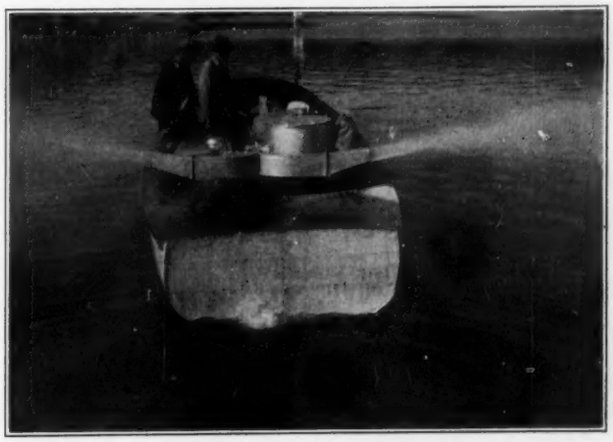
[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).



Los Angeles' Improved Dry-Feed Coppering Machines Used in Algae Control, Surface Applications Have Proved More Economical and Effective. All Shallow Areas Are Reached Easily.

COPPER AND HEALTH

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association* are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.

2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.

3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.

4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to drink it.

5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.

6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

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Associated with Hagan Corporation,

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1. Controls Corrosion

Calgon forms a thin protective film over metals and metal oxides at pH values of 5.0 and higher, reducing the attack of oxygen to such an extent that corrosion ceases to be a serious problem and "red water" is eliminated.

2. Prevents "Red Water"

Calgon added to well water as it is pumped prevents the precipitation of dissolved iron and so prevents "red water" from this source as well as that due to corrosion.

3. Stabilizes Water Following Lime or Lime-Soda Softening

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Where water is high in bicarbonate alkalinity, the use of Calgon affords a simple, economical means of eliminating the scaling-up of coils in water heaters.

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Calgon is a complex sodium phosphate glass produced by a thermal process from soda ash and food-grade phosphoric acid. Unadjusted Calgon glass contains not less than 66 per cent of P_2O_5. All impurities other than moisture total less than 0.2 per cent. Unadjusted Calgon glass has a pH of approximately 6.0 in 1 per cent solution.

Calgon Treatment

The amount of Calgon added is extremely small—from 0.5 to 2 parts per million of water. Since little or no equipment is required, the cost is well within the budget of most water departments.

Calgon Treatment is now being used successfully in more than 200 municipal water systems, ranging in capacity from 10,000 to 120,000,000 gallons per day. Calgon Treatment is no longer an experiment. It is a sound, accepted process, efficient, dependable and economical—a tested and proved success.

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St. Louis—J. T. McFarland, 1208 Continental Bldg.
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San Francisco—Griffin Chemical Co., 1000 Sixteenth Street.
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*Calgon is the registered trade-mark of Calgon, Inc., for its vitreous sodium phosphate products.

COPPER SULPHATE

Some Aspects of Its Usefulness and Methods of Application

By PAUL WEIR, Supt. of Filtration
Atlanta, Georgia

THE utilitarian value of copper sulphate in the water purification plant has now come of age and it should be considered in the same light as other chemicals in the water treatment field. It should be applied by calibrated equipment of a permanent nature and not promiscuously fed through a dilapidated contraption. Proper equipment means effective and economical control.

Copper sulphate is essentially chemically pure, 25% of its weight being pure copper. It can be secured in a variety of crystal sizes from large lumps to fine powder. It is conveniently packaged in wooden barrels and 100-pound bags.

Copper is usually applied at two principal points in the purification process:

I. Open storage reservoirs.
II. In conjunction with other purification chemicals.

Methods of Application

Alone

The following four methods are most generally used in treating open storage reservoirs, depending upon their size, intensity of organism, propagation, and available equipment.

(a) Porous bag suspension.
(b) Perforated dispersion box or basket.
(c) Solution spray—(surface atomization).
(d) Pulverized crystal blower—(surface dusting).

One of the simplest methods of copper sulphate application consists in the placing of about 25 pounds of the crystals in burlap bags, or porous baskets, and attaching them to a boat, either astern or at the sides, so that they will drag in the water to be treated. Additional refills may be used as needed. It has been frequently suggested that the boat should follow a definite course, one series of parallel paths from 20 to 50 feet apart, and if the reservoir is deep, a second course should be made at right angles to the first in grid-iron formation.

Another method has been developed at Atlanta, whereby the shore line and areas too shallow for boat travel may be treated in an effective and economical manner. An inflated automobile inner tube is laced with rope or heavy twine, in a spider web or net effect. This floating basket supports a 25-pound bag of copper sulphate. A 25 to 50 foot sash cord, attached to the inner tube, permits a person to pull this device easily from the shore line. Atlanta has two raw water impounding reservoirs with a total surface area of 60 acres. Each reservoir has approximately 6,000 feet of shore line which requires 150 pounds of copper sulphate thus applied each month.

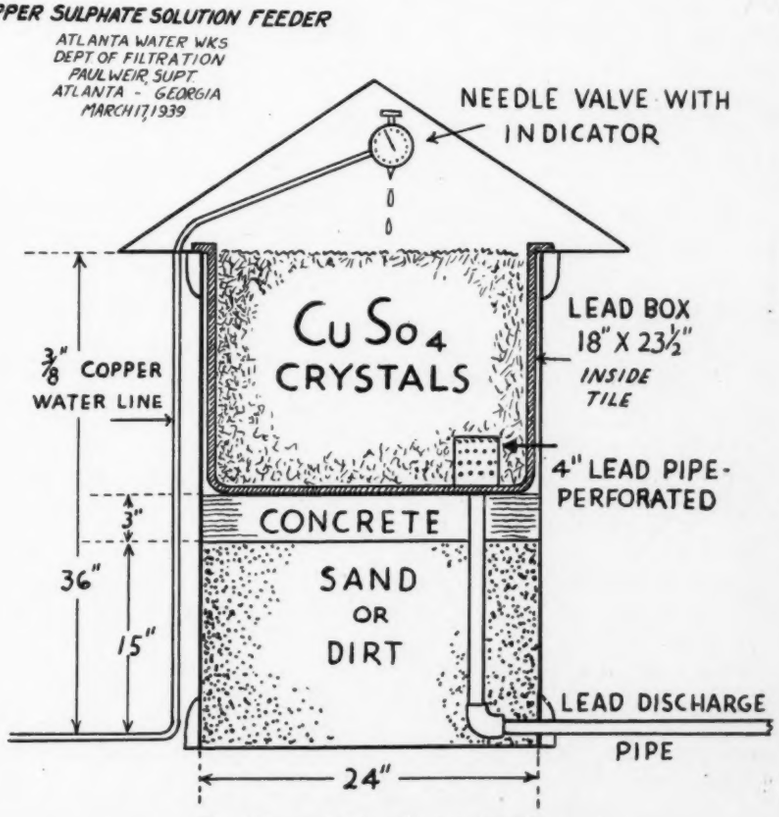
There are certain circumstances, however, that are not conducive to this simple method of treatment. It may be more expedient and economical, on the whole, to use the dispersion box and the spray or dry crystal blower methods of distribution.

With Other Chemicals

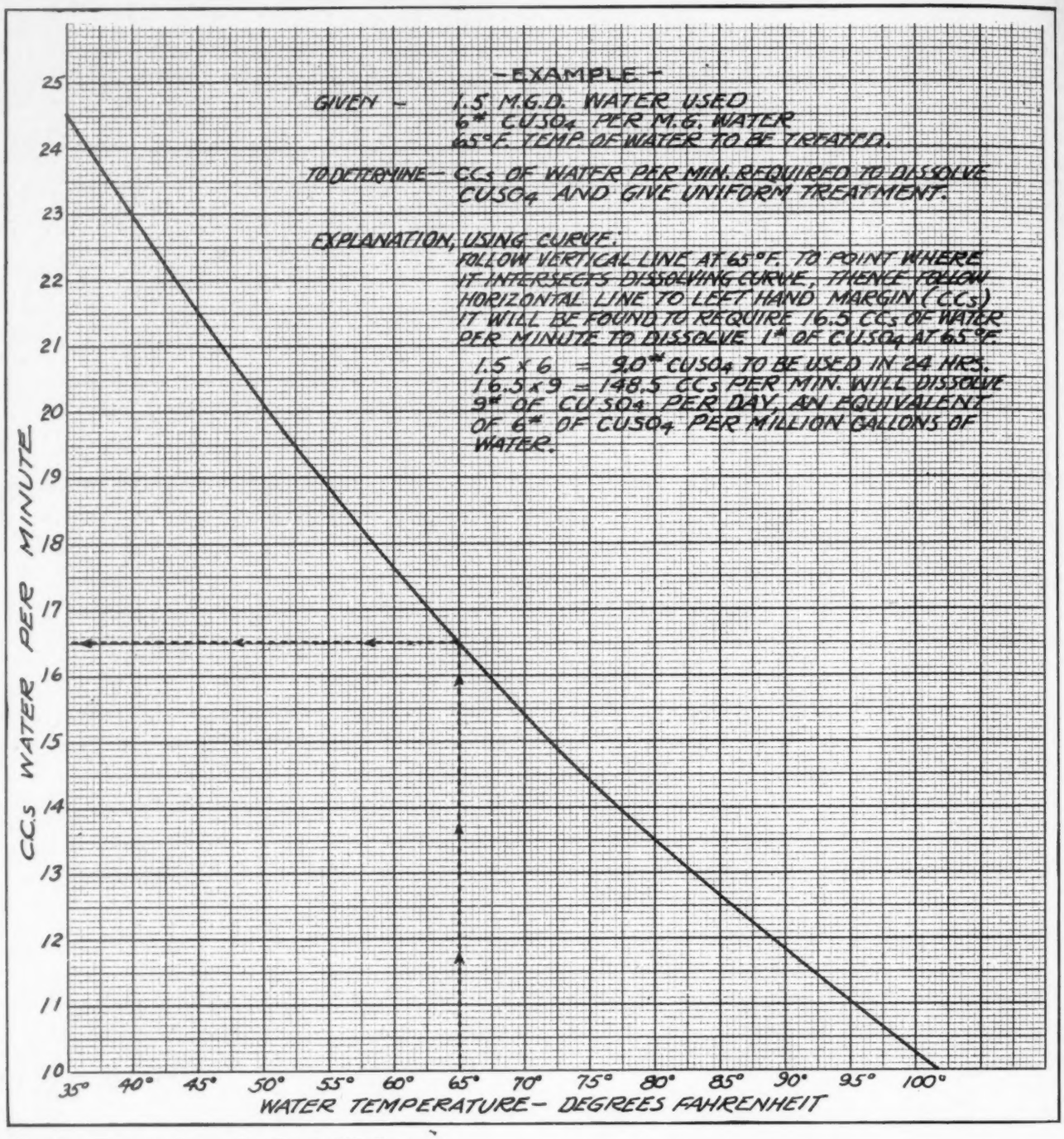
It has been frequently found necessary to apply copper sulphate continuously, at the inlet of the mixing chamber, or at other convenient points, during times when micro-organisms are most abundant and are not entirely reduced by reservoir treatment alone. This may be accomplished by making a concentrated solution in a paraffine-lined wooden barrel, or other acid resisting container. An orifice or stopcock drains the solution from the container into the water to be treated, necessitating recharging at frequent intervals. This type of equipment is usually a makeshift and is not conducive to uniform and economical feeding.

We at Atlanta have endeavored to make our copper feeding equipment permanent—(see illustrations). These feeders are of the solution type, and are mounted out-of-doors at the influent and effluent ends of the mixing chamber. A standard 3 foot length of 24 inch diameter terra cotta pipe is set in 4 inches of concrete grout, with the bell at the top. The lower 18 inches of this pipe is filled with sand and sealed with about 3 inches of concrete. Into the top 18 inches is fitted a circular lead container which rests upon the concrete slab. A heavy walled lead pipe of 1 in. diameter leads from the bottom of the circular lead container down and through the side of the terra cotta pipe and

One of the Atlanta Copper Sulphate Feeders
(Modified Shelton Design) Constructed by Atlanta Water Department (See detail sketch)



The Atlanta Copper Feed in Detail
(Note simplicity of construction and dosage control by needle-valve setting for water feed only)


-EXAMPLE-
GIVEN - 1.5 M.G.D. WATER USED
6# CUSO4 PER M.G. WATER
65°F. TEMP. OF WATER TO BE TREATED.
TO DETERMINE - CCs OF WATER PER MIN. REQUIRED TO DISSOLVE CUSO4 AND GIVE UNIFORM TREATMENT.
EXPLANATION, USING CURVE:
FOLLOW VERTICAL LINE AT 65°F. TO POINT WHERE IT INTERSECTS DISSOLVING CURVE, THENCE FOLLOW HORIZONTAL LINE TO LEFT HAND MARGIN (CCs) IT WILL BE FOUND TO REQUIRE 16.5 CCs OF WATER PER MINUTE TO DISSOLVE 1# OF CUSO4 AT 65°F.
1.5 x 6 = 9.0# CUSO4 TO BE USED IN 24 HRS.
16.5 x 9 = 148.5 CCs PER MIN. WILL DISSOLVE 9# OF CUSO4 PER DAY, AN EQUIVALENT OF 6# OF CUSO4 PER MILLION GALLONS OF WATER.
CCs WATER PER MINUTE
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85° 90° 95° 100°
WATER TEMPERATURE- DEGREES FAHRENHEIT

Courtesy—Tennesse Copper Co., Copper Hill, Tennessee

From This Graph Is Determined the Rate of Water Feed Required to Dissolve and Feed the Desired Dosage of Copper Use of the graph in arriving at the correct water rate setting per pound of copper sulphate required per hour is explained on the graph. The solution discharged is saturated, varying in concentration with the temperature of feed water, consequently the need for water temperature readings and use of this helpful graph.

to the point of application. A small, circular, perforated lead baffle fits over the inlet to the feed line to prevent stoppage. Dry crystals (random size) are placed in the circular lead dissolving pot. Water from a ⅜-in. copper line flows through a pressure reducing valve, thence through a small orifice, where it drips into the copper crystals, forming a uniform saturated solution of copper sulphate. This flows out at the bottom of the pot. The quantity of copper sulphate is readily controlled by a calibrated needle valve, which admits the water through the orifice into the bed of copper crystals. The water flow is set in accordance with the temperature-solubility curve, here reproduced, so as to secure the desired rate of copper application.

An attractive metal mushroom-type cover protects the equipment from the elements. This apparatus is inexpensive to build, easy to operate, and is subject to accurate calibration to give the required dose. Its neat design makes it an asset to any plant. It will operate without adjustment for days, still maintaining the original setting and feed rate. One decided advantage, over many other types of home-made equipment, is that the control involves the feeding of nothing more difficult than pure water through the small orifice, rather than a corrosive or encrusting solution, as is usually the case with solution feed equipment. Small particles of foreign matter or undissolved crystals soon obstruct most any type of restricted orifice when employed in feeding copper sulphate solution.

Dissolving Water at Constant Temperature

It becomes apparent, from a study of the accompanying chart, employed in arriving at the flow rate for the dissolving water

stream in dosage manipulation, that if the supply of dissolving water could be produced at a constant temperature, or at a temperature which fluctuates but slightly, a worth while advantage accrues.

To attain such a desideratum, or an approach thereto, consideration of a scheme for producing a supply of water at ground water temperature, as developed in the Atlanta Water Department, is suggested. This scheme is an invention of Mr. William Rapp, Atlanta's late Superintendent of Construction and Distribution, which was first described and illustrated in detail in "Water Works and Sewerage." The descriptive article and drawing was reprinted on page 65 of the Data Section of the very useful April, 1939, issue.

In brief, the scheme consists of employing an existing well, or putting a new 4 inch well down into ground water to such a depth that a 5 foot long coil, made up of pure copper tubing, may be submerged in the ground water for the most part, if not completely so. The inlet (upper end) of the coil connects to a drop pipe from the city supply main. The outlet (lower end) discharges through a ⅜ in. riser of copper tube, running up alongside of or through the center of the coil. The city water supply will be cooled or warmed, as the case may be, to the rather constant temperature of the ground water which is constantly moving across non-pumped wells, or upwards through pumped wells. By this method, in Atlanta, water has been cooled and kept flowing under main pressure at 66 deg. F., although the city water entering Mr. Rapp's "ground cooler" has been as high as 87 deg. F. during the summer period.

In connection with the production and displacement of a saturated solution of a chemical in dosage control, the matter of *what* temperature is not the important consideration, but rather the production of a fairly *constant* temperature feed water, and knowledge of the concentration of saturated solution at such temperature. Naturally, some thought must at the same time be given to insulation of the dissolving pot in order that the chosen water temperature may be maintained fairly constant while passing through the saturation-pot.

We realize that there are other methods of producing water at thermostatically controlled temperatures, with constancy, but we rather enjoy the idea of letting Nature contribute its bit through use of the economical and fool-proof equipment and scheme of the eminently practical Mr. Rapp.

Effect of Copper Sulphate on Organisms

Microscopic examinations and threshold odor tests are important in attaining efficient application and control of copper sulphate treatment. There is not one fixed dosage of copper sulphate suitable for any one condition; but, generally speaking, an application of 2 to 10 pounds per million gallons of water will be found effective in the elimination of the most objectionable microscopic growths. And, continuous application of small doses usually gives good results in bringing about practical elimination of most of the more common and troublesome types. A twelve month program of application, on larger reservoirs, and early season control in mixing chamber, etc., makes possible the use of small applications and effects a maximum of organism reduction without taste and odor formation.

Copper sulphate should be used to *prevent* microscopic growths in a water purification system, rather than to kill the organisms after they have grown to large numbers. A small quantity of copper sulphate applied continuously during the growing season, or certainly at frequent intervals, will keep growths at a minimum and will also prove over-all a more economical procedure.

When it is convenient to lower the water line in a water treatment plant or dewater it entirely, algae adhering to the walls may be eliminated by spraying or washing the exposed area with a 5% solution of copper sulphate.

Filter Bed Clogging

A number of water plant operators have experienced a partial if not an almost complete clogging of filter beds by micro-organisms. Greatest relief has been had when copper sulphate treatment was begun and continuously applied during the propagation season. Diatoma and synedra are usually the chief offenders and may be killed, or reduced, by using approximately 2 to 6 pounds of $CuSO_4$ per million gallons of water.

At Spartanburg (1), Marquis describes a situation where a new plant was put into service, after the supply reservoir had been idle a long time, permitting a luxuriant growth of algae. Rapid sand filters became so densely matted with algae that filter runs were reduced to 1½ hours between washings. The wash water consumption reached 25% of the total pumpage and the city was on the verge of a water shortage. Copper sulphate was immediately applied to an area 1,000 feet in front of the raw-water intake by dragging copper sulphate crystals in a burlap bag fastened behind a boat. Approximately 13 pounds of $CuSO_4$ were used for each million gallons of water. This treatment was continued daily until relief was apparent at the filter plant. After the initial emergency was over, copper sulphate was regularly applied by solution feed at the inlet of the mixing chamber. Dosages ranged from 2 to 13 pounds per million gallons. This same procedure has been followed yearly since, without similar reoccurrence.

A few years ago, Atlanta experienced the formation of troublesome sheets of microorganisms, in the impounding reservoirs, which reduced filter runs from 120 hours to 20 hours between washings. Taste and odor complaints ensued. This was rectified by monthly applications of $CuSO_4$, at the edge of the reservoir and also continuous application at the inlet of the mixing chamber, when the raw water turbidity drops below 25 p.p.m. At such times 2 to 7 pounds of $CuSO_4$ per million gallons of water are used to combat these growths, with satisfactory results. The continuous application of 4 pounds of copper sulphate per million at Atlanta, during periods of algae propagation, has materially reduced tastes and odors, chlorine consuming substances, and coagulant used. This results in a more palatable drinking water, at a reasonable cost, and filter runs at Atlanta are almost directly proportionl to the concentration of micro-organisms in the *applied* water.

The Question of Copper on Health

It is believed that the judicious use of copper sulphate to prevent and kill algae in water purification systems is not harmful to health and is sanctioned by practically every State Department of Health in the U. S. A. (2).

Reliable authorities (3) have more recently proven that doses of $CuSO_4$, as high as 100 pounds per million gallons, could be used with alum coagulation, if the pH of the water is above 6.3, without danger of copper passing the filters.

Negus (4) states that it is necessary for about 30 p.p.m. of copper ions (120 p.p.m. of copper sulphate) to be present in water to stain white plumbing fixtures. He further states that research and experience have proven that a copper limit of 0.2 p.pm. (about one-half the amount present in cow's milk) is much lower than necessary. Conservatively, five times this amount (1.0 p.p.m.) would still be considered safe.

Uses Other than as an Algaecide

Copper sulphate is said to increase the toxicity of ammonia-chlorine sterilization under certain conditions.

At Indianapolis the combination of pre-chlorination and copper sulphate has proved highly effective.

Copper sulphate has been successfully used, with aluminum sulphate, to control algae growths on the vertical side walls of reservoirs and basins. Eight to 16 pounds per million gallons of copper sulphate proved satisfactory in this undertaking (5).

Copper salts are highly effective coagulants and Damn and Bock (6) report that when milk waste was treated with two pounds of copper sulphate to between 225 and 275 cu. ft. of waste a good floc was produced. A clear effluent was obtained by passing the flocculated material through a magnetite filter. The precipitated sludge is said to have possibilities as a fertilizer.

Conclusions

Fundamentally, all structures entering into the storage, purification, and distribution of water supplies should be maintained in a high degree of cleanliness, free from slimes, growths and deposits. Treatment with copper sulphate continuously, where possible, or intermittently where absolutely necessary due to local conditions, accomplishes this.

Experience in many plants shows that copper sulphate contributes to better operation not only through algae control but betterment of plant operation by its effect upon floc, filter condition, and appearance of finished water.

During 40 years of usage copper sulphate has demonstrated its indispensability in water treatment and deserves regard as one of our most important water purification chemicals.

Like the famed "ounce of prevention," a pound of copper effectively timed and placed is worth more than "tons" of regrets and explanations.

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3. C. J. Brockman—"Adsorption of $CuSO_4$ by Aluminum Floc," J. SE Sec. A.W.W.A., 1933. Dr. Parker, SC.B., W. W. Eng., June 28, 1932.
4. Sidney S. Negus—"Physiological Aspects of Mineral Salts in Public Water Supply," A.W.W.A., Jour. Feb., 1938.
5. G. F. Gilkison—"Use of $CuSO_4$ in Kansas City Reservoir," Public Wks., Mch., 1921.
6. Damn & Bock—Pub. Health Abs., Apr. 1937.

INTERNATIONAL FILTER CO.

Water Conditioning, Sewage Treatment, Hydraulic Control and Chemical Feed Equipment

325 W. 25TH PLACE, CHICAGO, ILL.

PRODUCTS

Aerators—MultiCone, forced draft, coke tray, cascade and spray
Boiler Water Purification Plants
Carbon Purifiers—Taste, odor and color removal plants
Chemical Feeders—Dry and solution types, combination mixers and feeders
Color Removal Plants
Controllers—Chemical feed, rate of flow, liquid level, hydraulic valve
Filters—Concrete and wood gravity, pressure, and disk type water filters; also oil removal, swimming pool, etc.
Filter Plant Equipment—Controls, gauges, indicators, recorders, operating tables, transfer switches, coagulators, etc.
Fluorine Removal Plants
Gauges—Rate of flow, liquid level, etc.
Iron Removal Plants
Lime Feeders and Slakers
Proportioners—Acid and chemical feed
Sewage Treatment Equipment—Activators, Accelo-Filters, coagulators, clarifiers, dosing siphons, rotary distributors, samplers
Softening Plants—Lime-soda, Hot-flow, Accelator, Zeolite.
Steam and Gas Purifiers
Sterilizing Equipment
Swimming Pool Equipment—Filters, cleaners, fittings, etc.
Taste and Odor Removal Plants
Venturi Tubes
Water Filters and Filter Plant Equipment
Water Softening Plants of all types
Water Stills
Zeolites and Zeolite Water Softeners

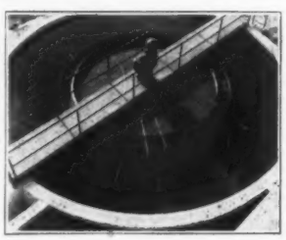
WATER CONDITIONING EQUIPMENT

INFILCO SERVICES

INFILCO has specialized in the design and manufacture of all kinds of water conditioning equipment—from aerators to underdrains—for over forty years.

The consulting engineer or his client can specify "Infilco" throughout the water treating plant knowing that such equipment has the benefit of Infilco's vast experience in supplying thousands of installations. Specifying one brand of equipment throughout gives the added assurance of undivided responsibility and coordinated results. The services of Infilco's staff of competent engineers and their complete laboratory facilities, ready to cooperate in making recommendations and reports, are at the disposal of the consulting engineer or his client.

ACCELATOR SOFTENERS, CLARIFIERS AND STABILIZERS

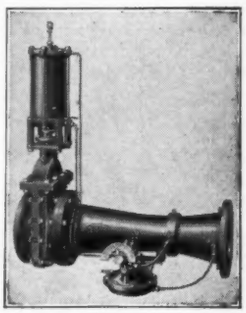


The Accelator for water softening, clarifying and pH correction is one of the most important water treatment developments in recent years. While retaining all of the advantages found in the conventional lime or lime-soda processes, it offers many new advantages. Treating, mixing, reaction and clarification, all are carried out in an incredibly small space. Treating chemicals are applied in a new way. Reactions occur under new conditions. Size is but a fraction of that for old type plants where design was based upon holding time requirements for chemical and physical reactions and for sedimentation.

ZEOLITES AND ZEOLITE SOFTENERS

Infilco Zeolite Softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic or full automatic operation as desired. A variety of Infilco Zeolites are available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco Zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.

CONTROLLERS, GAUGES



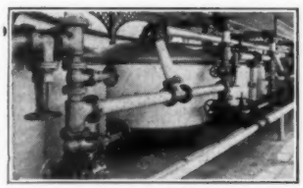
Infilco Rate of Flow Controllers, for automatically maintaining uniform rates of flow, are noted for their accuracy, low loss of head, reset and rate setter features. Infilco Water Level Controllers operate hydraulically controlled valves to maintain proper liquid levels.

Infilco Indicating and Recording Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

PRESSURE AND GRAVITY FILTERS

Clean, clear water, essential for municipal supply, is assured by Infilco pressure or gravity type filter plants, in capacities from a hundred gallons per day up.

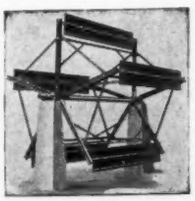
The design of every Infilco filter plant is based upon sound engineering principles, backed by over four decades of experience in equipping many hundred municipal water works, and building tens of thousands of industrial filters.



RECARBONATORS

Infilco Recarbonators are available for the stabilization or recarbonation of industrial liquids, trade wastes and lime-softened water. Infilco equipment provides for the complete process of producing, cooling, scrubbing, compressing, drying and applying carbon dioxide gas to the liquid.

COAGULATORS



Infilco Coagulators promote economy and efficiency in the chemical treatment of water and sewage. The applied chemicals are fully utilized by bringing them into intimate contact with the liquid undergoing treatment. The suspended particles are collected rapidly and quickly aggregate into masses having very high subsiding values.

TRANSFER SWITCHES, OPERATING TABLES ROBOTROLS AND SAMPLING TABLES

Infilco Transfer Switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco Operating Tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

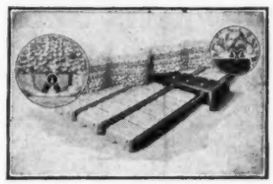
The Robotrol is a robot filter or softener operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently and without supervision.

Sampling tables furnish a visual check on the condition of raw, settled and filtered water.

HYDRODARCO PURIFIERS

Hydrodarco is the activated carbon made expressly for water purification. Hydrodarco Purifiers, employing beds of granular Hydrodarco, automatically remove tastes, odors, chlorine, iron, organic color, etc. They are furnished in capacities from a few gallons per hour to millions of gallons per day.

INFILCO FILTER UNDERDRAINS



Wagner Filter Underdrains provide a primary distributing system of a manifold and laterals on wide centers, with distributing orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

FLUOREX PURIFIERS

Fluorex is a specially prepared, highly porous and reactive tricalcium phosphate for removing fluorine from water. Fluorex Purifiers, with their improved method of regeneration which prolongs the active life of the adsorbant and makes possible the use of ordinary materials and construction, offer the ideal means of removing fluorine.

AERATORS

To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Chemical Feeders—dry or solution—provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form: liquid, powdered, granulated or lump. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Feeders and Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking crushed or pebble quicklime, followed by the preparation and delivery of a suitable milk of lime mixture.

Infilco Proportioners maintain predetermined ratios between liquid or solid flows, or automatically vary the ratio of one flow with respect to another, by electric, hydraulic or mechanical means.

SEWAGE TREATING EQUIPMENT

INFILCO manufactures equipment for all sewage treating processes—chemical, biological and mechanical. In offering many products for application in these various processes, Infilco also offers the user the advantage of centralized responsibility, which is important in assuring continued satisfactory equipment operation.

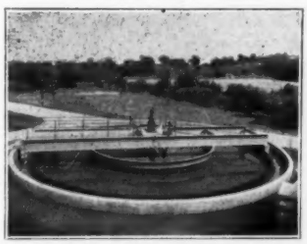
For making recommendations and reports to the consulting engineer and his client, Infilco extends its laboratory facilities and the service of its staff of engineers. It is of course not intended that this service shall conflict with the work of the engineer; rather, it is meant to be in cooperation with this work.

ACCELO-FILTER SYSTEMS

The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the biological filter at a considerably higher dosage rate.

Aero-Spray Nozzles on a rotary distributor (above) provide a fan-shaped variable spray which assures optimum coverage and maximum aeration in the application of screened, settled sewage to trickling filters. All parts of these improved nozzles are bronze to assure long life.

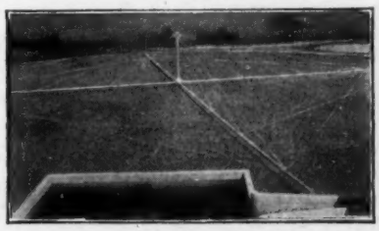
CLARIFIERS



Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation of a sewage concentrator. These Clarifiers are designed with curved rotating scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

The two different sizes of Infilco Clarifiers assure effective removal of solids from the sedimentation tank whether it be small or large. The WS Clarifier with central motor reducer drive is supplied for tank diameters up to 40 feet. For diameters larger than 40 feet, there is the PD Clarifier, driven by a horizontal motorized reducer through a pinion which meshes with a stationary rack at the tank periphery.

ROTARY DISTRIBUTORS AND DOSING SIPHONS



Only Infilco Rotary Distributors offer so many important refinements such as full-opening arm end gates, mercury seal with protective seal ring, and corrosion-resistant nickel iron castings, along with low operating head requirements and uniformity of distribution. Infilco dosing siphons insure perfect operation of distribution mechanism at all flow rates.

WATER SOFTENING*

With Particular Reference to Its Economic Aspects

By CHAS. P. HOOVER

Superintendent of Purification

Columbus, Ohio

The consumer judges water to be hard if much soap is required to produce a lather, and soft if it lathers freely. The hardness of most water supplies is due to four compounds which are held in solution. These compounds are:

1. Calcium bicarbonate (solution of limestone, $CaCO_3$, in waters containing carbon dioxide, CO_2).
2. Magnesium bicarbonate (solution of magnesite, $MgCO_3$, in waters containing carbon dioxide, CO_2).
3. Calcium sulphate (in the form, $CaSO_4.2H_2O$, is known as gypsum).
4. Magnesium sulphate (in the form, $MgSO_4.7H_2O$, is known as epsom salts).

As long as any of these compounds or a combination of them are present in a water supply it is hard.

Chlorides and nitrates of calcium and magnesium are sometimes present.

Calcium and magnesium bicarbonates were formerly designated as temporary hardness, but are now termed carbonate hardness.

Calcium and magnesium sulphates, chlorides, and nitrates were formerly designated as permanent hardness or incrustants, but are now usually called non-carbonate hardness.

Water softening processes remove objectionable iron compounds and manganese as well as hardness.

In general terms, hard water is made soft by a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form, and then by removing the insoluble compounds by sedimentation and filtration, or by an exchange process, which consists in replacing the calcium and magnesium with sodium. The first process is known as the chemical, or lime-soda process, and the second, the zeolite process.

[Elsewhere in this issue appears a map of the United States which reveals the average hardness of public water supplies of important American municipalities, of each State.—*Ed.*]

History

The art of water softening with lime dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water caused a deposition of the carbonates of calcium and magnesium. The proposal to use lime for softening hard water on a plant scale was advanced by Thomas Henry in England about 1800, but it was not until 1841 that water softening on a large scale was developed by Dr. Thomas Clark of Aberdeen, Scotland. He patented the process of adding lime to water to precipitate earthy carbonates held in solution by carbonic acid.

Winnipeg, Canada, built the first municipal plant in 1901. In 1903, the first municipal plant in the United States was built at Oberlin, Ohio.

In 1908, water softening on a larger scale than had hitherto been tried was undertaken at Columbus, Ohio, when a plant having a capacity of thirty million gallons per day (now 50 m.g.d.) was constructed.

For years the advantages of water softening were offset to a certain extent by disadvantages. Difficulties arose in operating sand filters on account of incrustation of the sand with calcium carbonate. Water mains, service pipes and meters became clogged with heavy deposits. When water contained an excess of causticity it was unpalatable. The recarbonation process developed by Archbutt and Deeley in the latter part of the last century, was employed at several plants in England for the purpose of overcoming all the above difficulties, but its first employment in this country, on a successful plant scale, was in 1921 at Defiance, Ohio. Since that time practically all water softening plants have been equipped with recarbonation devices.

The chemistry of water softening is now well understood, and an exact prediction of the results to be obtained can be made. Improvements in design and equipment for applying chemicals and removing sludge all tend toward simplifying operation. As a result of these improvements there has been a decided trend toward some degree of water softening by municipalities throughout the United States. Industry has gone forward with water softening to a far greater extent because of proven economies in processes, materials and equipment where soft water is made available.

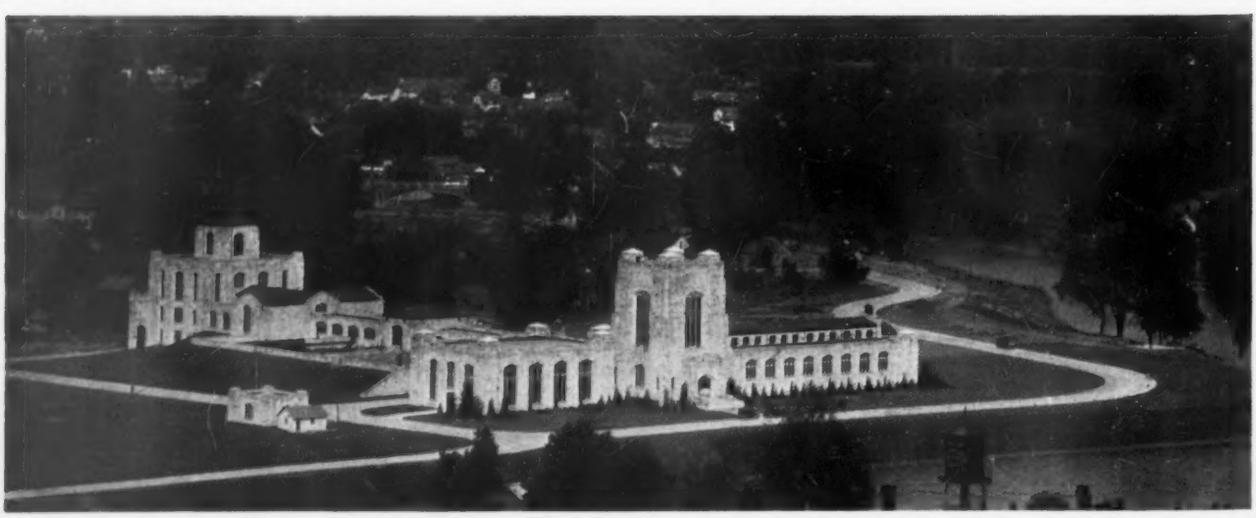
Economic Aspects of Water Softening

The water supply in a large number of cities and villages should be softened because:

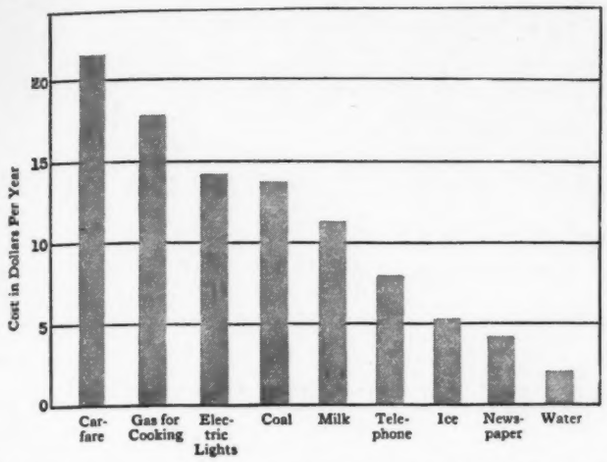
1. Hard water destroys soap; makes household work more difficult; has a bad effect on clothes washed in it, on plumbing, heating systems, boiler tubes and shells; and is unsuitable for many industries.
2. Softening at a central source of supply rather than in thousands of homes is economically sound.

It is cheaper to pay a reasonable additional charge for centralized softening than to accept a hard supply, a portion of which must be softened in the home. All of us, whether we

* Excerpts from "Water Supply and Treatment"—written by Mr. Hoover and published by the National Lime Association.



The Water Softening Plant of Fort Wayne, Indiana



Cost Per Capita Per Year for Domestic Services (Family of Five)

know it or not, soften some water each day, for it is necessary to use soft water to keep clean.

All public water supplies contain some hardness and that portion of the water in which soap is used must be softened to be effective. Soap has very little cleansing action until it lathers and it will not lather until the hardness salts in the water have been neutralized by it.

Aside from the objections of the precipitated soap curd, the extravagance of removing hardness with soap can be appreciated when it is realized that a pound of lime costing approximately one-half cent will neutralize as much hardness as 20 pounds of soap costing approximately $3.00.

Soap Losses Determined Experimentally

The amount of soap consumed and the quantity of water used for household processes, laundering, dish-washing, cleaning, washbowl activities, and bathing, was carefully measured for a period of one week, and calculated for a year.[1] Two kinds of water were used, each for one week: (1) Scioto River water which was filtered and sterilized but not softened. The hardness was 270 parts per million (16 grains per gallon). It was delivered in 10-gallon bottles to the home where the experiments were made. (2) Softened water as delivered to consumers. The hardness averaged about 80 parts per million (4.7 grains per gallon). In the home where the experiments were made there were five people, three adults and two children. Ivory soap in bar and flake form was used, the former costing 21 cents per pound and the latter 31 cents. The laundering was done in a vacuum type electric washer, the weight of the clothes averaging 29 pounds per washing.

Water-works records show that this family used the average quantity of water, about 30 gallons per day per capita. Their bill amounted to 75 cents per month. The soap was dried and weighed before and after it was used, so that the difference in weight would represent the weight actually used. The results for the week figured to one year show:

1. That this family used 281 gallons of water a week for ordinary household cleaning, divided as follows: Laundry, 15 gallons; dish-washing, 73 gallons; cleaning, 4 gallons; bathing, 136 gallons; and washing of hands, 53 gallons.
2. That approximately 11.46 pounds of soap were used per week with unsoftened water, or a total of 596 pounds per year.
3. That approximately 3.7 pounds of soap were used per week with Columbus city softened water, or a total of 192.5 pounds per year.
4. That softened water saved this family 403.5 pounds of soap per year.
5. That this soap, valued at 20 cents per pound, represented a saving of $80.70 per year and figured at 12 cents a pound, the price of cheaper laundry soaps, represented a saving of $48.42.
6. That this consumer could afford to pay five or six times as much for softened as for unsoftened water.

The investigation also disclosed the following facts:

1. One-half again as much time was needed to launder clothes in the unsoftened as with the softened water.
2. The cleanliness of clothes washed in the unsoftened water was not entirely satisfactory. Several very soiled pieces had to be rewashed and all of the clothes had to be re-rinsed.
3. The general appearance of the clothes was unsatisfactory.

These figures may be high for the average family but they are fairly representative for a family of five living in moderate circumstances. There are 55,033 domestic services or consumers in Columbus, Ohio. Applying the above figures, if each one saves $48.42, the total saving would amount to $2,664,697.86. If this figure is divided by two because of the possible use of cheaper compounds to "break" the water, the saving would be $1,332,348.93. This amount is about eight or ten times the cost of chemical softening.

Relations of Soap Wastage to Quantity and Type of Water

The above experiment demonstrated that 8 gallons of water per day per person were used for household processes. This quantity was probably not all completely softened by soap. Other workers have made the following estimates of water completely softened per capita per day:

	Gallons
Foulk[2]	0.9
Report of Special Committee for Madison, Wis.	1.7
City of St. Louis[3]	1.0
Average	1.2

The amount of soap required to reduce the hardness of 1,000 gallons of water, one part per million, has been determined as being 0.2 of a pound (Foulk's formula: Pounds of soap consumed per 1,000 gallons $= 2 + 0.2H$).

Based on these assumptions, the loss per family of five using water of varying degrees of hardness is shown in the following table:

SOAP WASTAGE AND COST WHEN USING WATER HAVING HARDNESS VARYING FROM 150 TO 500 PARTS PER MILLION

Raw water hardness p.p.m	Hardness removed by softening	Hardness reduced to	Loss lbs. of soap per family of five per yr.	Loss per family of five per year*
150	65	85	28.5	$3.40
200	115	85	50.0	6.00
250	165	85	72.5	8.70
300	215	85	94.0	11.30
350	265	85	116.0	13.90
400	315	85	138.0	16.55
450	365	85	160.0	19.20
500	415	85	182.0	21.85

*Soap at 12 cents per pound.

Actual Survey of Retail Soap Sales

The economic effects of quality of water, with special reference to soap consumption in the home, were demonstrated by H. W. Hudson[4] in a field survey of retail soap sales in four cities of the middle west: Superior, Wisconsin, and Bloomington, Champaign-Urbana, and Chicago Heights, Illinois. A canvass of all retail stores selling soap in these cities was made by a personal investigator who compiled a complete record of soap sales. The soap sales and per capita soap consumption with different types of water are shown in the following tables:

TOTAL SOAP SALES IN FOUR CITIES

City	Annual soap sales, pounds	Annual soap sales, dollars
Superior, Wisconsin	1,530,314	$196,133
Bloomington, Illinois	1,517,658	215,528
Champaign-Urbana, Illinois	2,093,881	307,732
Chicago Heights, Illinois	1,009,503	159,910

PER CAPITA SOAP CONSUMPTION WITH DIFFERENT TYPES OF WATER

City	Total hardness of water supply p.p.m.	Annual per capita soap consumption pounds	Annual cost of soap per capita dollars
Superior, Wisconsin	45	29.23	$3.75
Bloomington, Illinois	70	32.13	4.48
Champaign-Urbana, Illinois	298	39.89	5.93
Chicago Heights, Illinois	555	45.78	7.50

[1]Thesis presented for the degree of Master of Science by Miss Pauline Snyder, Ohio State University, 1927.

[2]Geological Survey of Ohio, Bulletin 29, 1925.

[3]Report of Water Commission, 1922.

[4]Abstract of thesis for Doctor of Philosophy in Economics, University of Illinois, 1933.

The results show.

1. That soap bills increase as the hardness of the water with which soap is used increases.
2. That even with a relatively soft water, a considerable quantity of soap is required to remove dirt and grease.
3. That by taking Superior as a basis for comparison, the annual per capita soap waste is: Bloomington, 2.9 lbs.; Champaign-Urbana, 10.7 lbs.; Chicago Heights, 16.6 lbs.
4. That this loss in Chicago Heights would amount to $15.00 per year per family of four.

From the results of this study an equation was formulated to show the degree of hardness necessary in any particular water supply in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening.

$$X = \frac{C - 75D + 75F}{F - D}$$

X = hardness of water supply in p.p.m., the softening of which will be paid for in soap economy alone.
75 = demonstrated attainable hardness of water in p.p.m., from municipal water softening plants.
F = soap waste per capita per year per p.p.m. hardness.
C = capital overhead charges, including superintendence, per capita per year.
D = cost of chemicals per capita per year per p.p.m. hardness.

Mr. Hudson states that if this equation is applied to data for Champaign-Urbana and the hardness of the raw water tested only 145 p.p.m. (it is actually 298 p.p.m.) a municipal water softener that would soften the water to 75 p.p.m. would save enough in soap for home use alone to pay for itself.

Effect of Hard Water on Power and Heating Systems

Heating hard water causes it to deposit scale in water pipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale, 1/50 to 1/9 inch thick, has been computed to be from 7 to 16 per cent.[5] This means that with scale 1/9 inch thick, 16 cents of every dollar paid for coal is lost. This is in addition to the trouble, cost of drainage, and time lost in getting rid of the scale. According to an estimate of the American Railway Engineering Association,[6] the damage caused by one pound of scale is 13 cents. The Association further estimates that the improvement in operating and maintaining locomotives, due to water softening, amounts to a saving of from $4,000 to $9,000 per locomotive per year.

Hard Water Stunts Growth of Cities

A study of ten Illinois cities shows[7] that eight have comparatively soft water supplies as judged by midwestern standards, whereas the other two have supplies that are excessively hard. The two hard water cities will be designated as A and B. Both are situated in rich agricutural sections and are advantageously located with respect to large markets. In spite of these advantages they have shown a very slow rate of growth. In 1880, A and B together had 26 per cent of the total population of the ten cities. In 1920 they together had only 13.7 per cent.

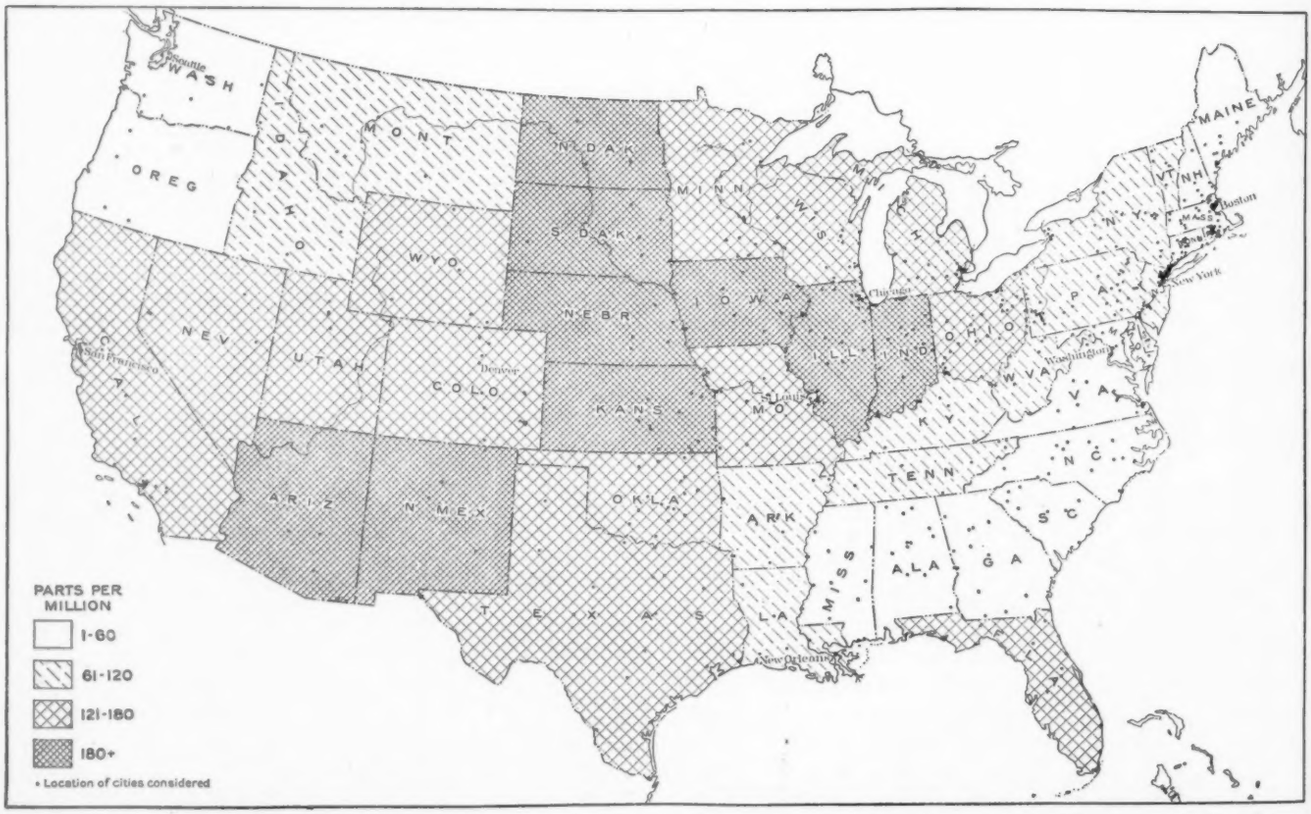
Manufacturing industries which require soft water for their successful operation, in establishing plants select communities having satisfactory water, other things being equal.

Cost of Softened Water vs. Other Commodities

"Cheap as dirt" is a common expression, but even expensively treated water is *much* cheaper! Two hundred and forty-one gallons of water equal one ton. Five cents a ton would be a little over 20 cents per 1,000 gallons, which is more than the average consumer pays for water in the larger and medium sized cities. A ton of dirt delivered would cost many times this amount.

The cost per capita per year for various domestic services by a family of five in Columbus, Ohio, is shown in the chart on the preceding page.

[5] U. S. Bureau of Mines, Tech. Paper 218.
[6] Bulletin, American Railway Engineering Association, November, 1923.
[7] Alvord, Burdick & Howson (Chicago), a private communication.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

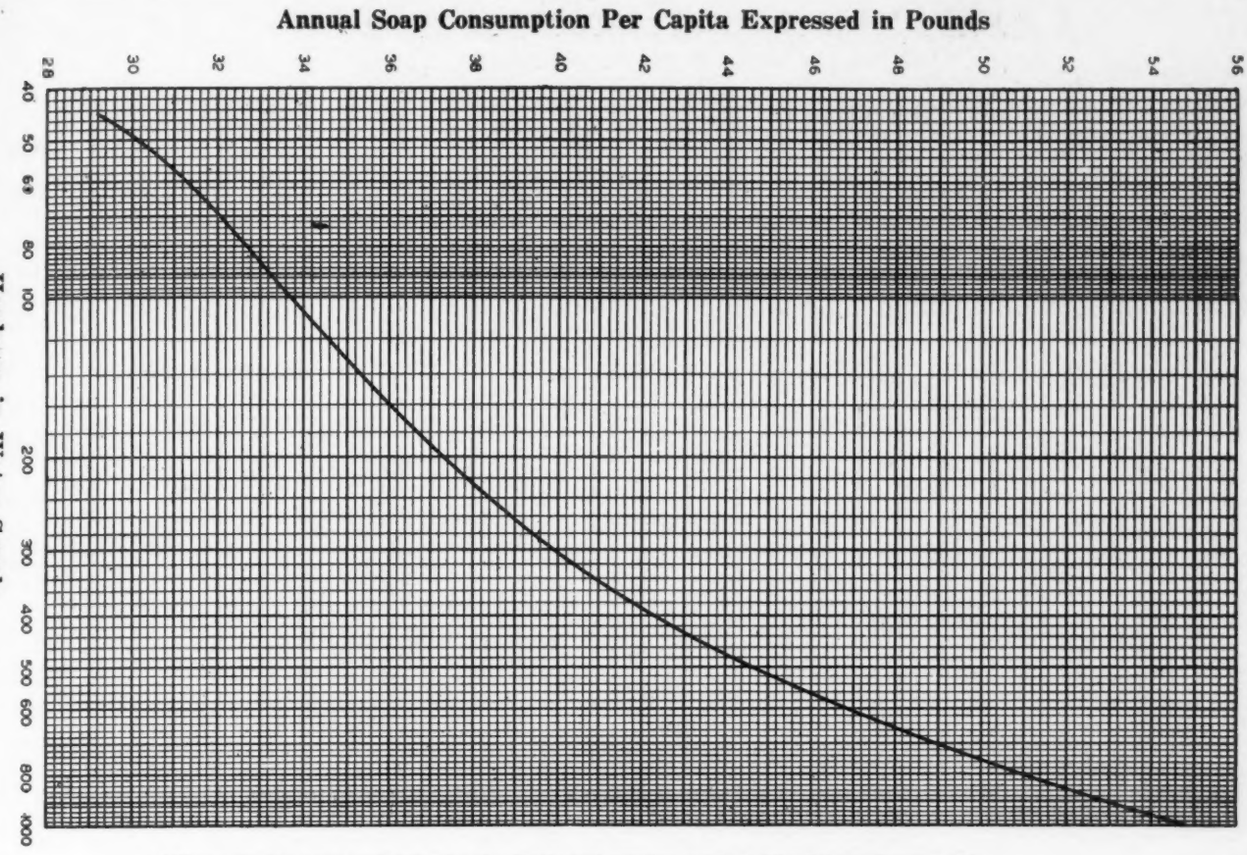

Annual Soap Consumption Per Capita Expressed in Pounds
28 30 32 34 36 38 40 42 44 46 48 50 52 54 56
40 50 60 80 100 200 300 400 500 600 800 1000
Hardness in Water Supply
Expressed in Parts Per Million of $CaCO_3$

Fig. 1.—Annual Soap Consumed per Capita for Waters of Various Degrees of Hardness

[These graphs were prepared by the Technical Service staff of The Solvay Process Co. from soap consumption data compiled by H. W. Hudson and published in the A.W.W.A. Journal—Vol. 25, p. 645, 1933. These graphs and other valuable information on water treatment appear in Solvay's Technical Bulletin No. 8.]

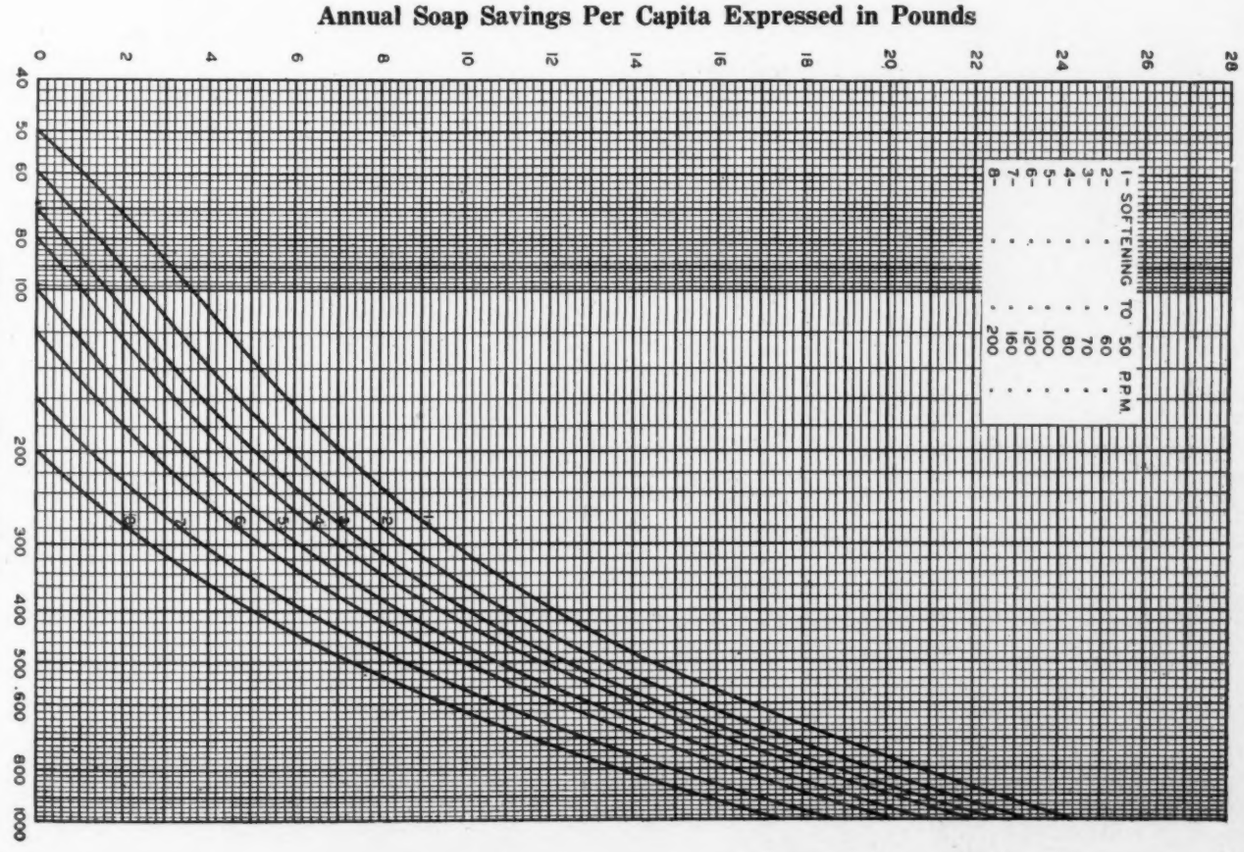

Annual Soap Savings Per Capita Expressed in Pounds
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
40 50 60 80 100 200 300 400 500 600 800 1000
Hardness in Water Supply
Expressed in Parts Per Million of $CaCO_3$
1- SOFTENING TO 50 P.P.M.
2- 60
3- 70
4- 80
5- 100
6- 120
7- 160
8- 200

Fig. 2.—Savings in Soap per Capita Resulting from Softening to Various Degrees

OMEGA MACHINE CO.

4010 Penn Ave., Kansas City, Mo.

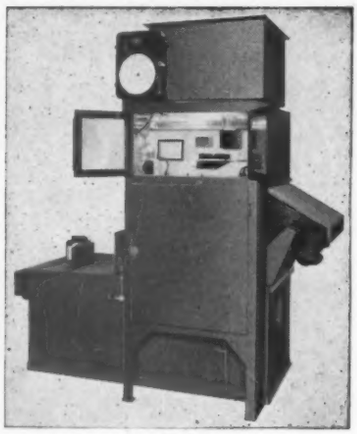
REPRESENTATIVES

Atlanta, Ga.—W. D. Taulman, 175 Spring St., S. W.
Detroit, Mich.—Wm. A. DaLee, Inc., 4835 Woodward
Hawaii—Alan Duvall, Box 33, Honolulu
Los Angeles—Chas. P. Crowley, 609 S. Anderson
Louisville, Ky.—R. M. Overstreet, 1317 S. 4th St.
New York City—Triangle Equipment Co., 50 Church St.
Philadelphia, Pa.—Alan A. Wood, 2045 N. Broad St.
Toronto, Ontario—Control & Metering, 454 King St. West
Brazil—Oscar Taves & Co., Box 840, Rio de Janeiro
Colombia—MacDonald & Peterson, Ltd., 502 Banco de la Republica, Bagota.
Argentine—Fiore Co.—Paseo Salon 285—Buenos Aires

EQUIPMENT

For Dry Material	*For Liquids*
Batch type Gravimetric Feeders	Precision Feeders
Belt type Gravimetric Feeders	Rotodip Feeders
Weighcheck Feeders	Proportioning Pumps
Universal Volumetric Feeders	Laboratory Stirrers
Lo-Head Feeders	Lime Slakers
Disk Feeders	High Speed Agitators
Dust Removers and Filters	Slow Speed Agitators
Combined Bucket Elevators & Feeders	Automatic Proportional Control

GRAVIMETRIC FEEDER AND SLAKER



A size No. 1 Gravimetric Feeder with 2,000 lb. hopper and mechanical operation recorder is illustrated mounted over a Lime Slaker. Slaker sizes range from 175 lbs. to 6,000 lbs. per hour.

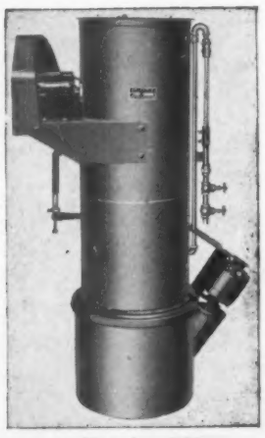
In this type Gravimetric Feeder the entire hopper load of chemical is carried on the scales which control the rate of feed. Errors cannot be cumulative.

BELT TYPE GRAVIMETRIC FEEDER

Weighs the material as it is fed on a short section of conveyor belt which is mounted on accurate scales. These feeders may be connected directly to large overhead storage bins if desired.

Accurate feeding range is from 5 lbs. to 3,000 lbs. per hour. A totalizer shows the number of pounds of material that have passed through the feeder.

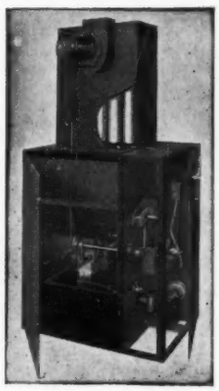
UNIVERSAL FEEDER



Rugged, accurate Volumetric Feeders. Designed to be used with extension hoppers or with overhead storage bins.

The No. 3 size Universal Feeder illustrated has a lead lined mixing chamber and motor driven, stainless steel agitator for dissolving Ferrisul. The water supply to the mixing chamber is measured by a Rotometer. Separate values are used to regulate and to shut off the water supply.

LO-HEAD FEEDER



Large hopper capacity with only 45" filling height. Rates of feed from 1 to 200 lbs. per hour. Cabinet type illustrated with feeding and driving mechanisms completely enclosed in separate compartments.

Any Omega feeder may be equipped with the dust remover and filter illustrated. The filter may be connected to several machines to remove dust incident to filling the hoppers with carbon, lime, etc.

PRECISION FEEDER

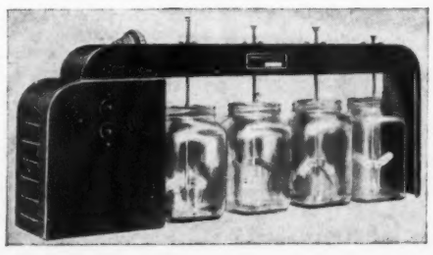
The most accurate and simplest type of feeder for solutions or light suspensions. Rate of feed is set by a dial to desired percentage of maximum rate. Feeding capacities range from 1/25 to 400 gallons per hour. Electric or spring motor drive.

Tanks may be equipped with dissolving baskets and agitators for dissolving lump material. Tank sizes 25 to 400 gallons.

ROTODIP METER

For feeding from large supply tanks which may be located at a distance from the feeder. Feeding range 1 to 800 gallons per hour. Galvanized, rubber covered or plain steel construction. Variable speed drive gives an infinite number of speed changes from zero to maximum rate.

LABORATORY STIRRER



For jar tests, to determine proper coagulant or carbon dosages. Also ball mill or tumbler type for agitating material in closed vessels, for threshold treatment tests.

LIME AND LIME SLAKING

By H. E. LORDLEY
Plant Manager, Department of Public Utilities
Richmond, Va.

LIME is one of the oldest chemicals known to civilization, yet today the efficient utilization of this important chemical is impeded by lack of complete information concerning its physical and chemical properties. Since lime is used in such large quantities for softening and corrosion control in the water works field, it is amazing that so little information is to be found in water works literature on the subject of lime and lime slaking.

There Is Lime and Lime

Limestone, which is the source of the calcium oxide, will vary in physical and chemical properties in different parts of the country. Some limestone is high in magnesium which is objectionable for use in water purification plants, yet suitable for other chemical processes. Other sources are high in iron and silica, so it is well to study an analysis of the raw stone before buying lime for the water plant. At the lime plant, in the first step of processing the rock for calcining, a superoir finished product results if mud, sand, and other impurities are removed before burning. In the actual calcining step, the manufacturer can control both the physical and chemical properties of the lime, either by the type of kiln or the method of firing. Therefore, we get much lime that is either under-burned or over-burned by lack of control of the process at the kiln.

Take, for example, the old style vertical kiln using coal as a source of heat without modern control equipment, we find that the lime thus burned will slake very slowly. On the other hand, the modern controlled rotary kiln produces lime that will slake so rapidly that it actually explodes in the slaker. The author recalls an amusing incident at the Richmond Filter plant on changing from a vertical kiln to a rotary kiln lime. The operator frantically called to report that the lime slaker was out of order and making a terrible rumble in the slaking chamber. On investigation, the new rotary kiln lime was producing miniature explositions that sounded like a loose agitator blade. Also common to the old style vertical kiln is the large percentage of core as compared to practically core-free lime from the rotary kiln. So we see that all lime is not the same from every lime plant and the water works executive must choose the source of lime carefully if highest efficiency is to result.

As to Lime Properiies

After the lime leaves the kiln it must be graded as to size. Quicklime can be furnished in sizes varying from a fine pulverized product, which will pass a 200 mesh screen, to a pebble lime of two inch size. In determining the proper size to use in the plant, the operator must remember that the pulverized lime offers both a dust problem and a feeding problem due to arching in the hopper. Dust can be controlled by proper ventilating system, but archhing is just a universal worry. Arching can be partly corrected by design of light weight hoppers having a bottom slope of not less than 60° from the horizontal. "Syntron" vibrators on the side of the hopper will further reduce arching, but the best answer is the use of pebble lime of size from ¼ inch to ¾ inch, provided suitable feeding and slaking equipment is available. Dust is reduced, arching in hopper is eliminated, and air-slaking of lime in storage is not as rapid with pebble lime as with the pulverized lime. Another physical property of interest is the color of the lime; white, gray, black, blue, etc. All are high in calcium oxide, and color is not a criterion of a good lime. The chemical properties and specifications are easy to determine in the laboratory. The lime should contain not less tran 90 per cent CaO, have a low magnesia, silica, and iron content, and be free of arsenic.

In many plants today, calcium hydroxide (hydrated lime) is preferred to calcium oxide, due largely to lack of information and equipment for slaking the oxide. The lime manufacturer is anxious to dispose of calcium hydroxide, since all fines from calcium oxide are converted into calcium hydroxide at the lime plant. The water works executive must remember that he pays for slaking process plus freight on water in hauling hydrated lime in preference to burned lime.

Economic Considerations

TABLE I

	Typical Calcium Oxide Lime	Typical Calcium Hydroxide Lime
Insoluble Residue	1.57	.37
R_2O_3	.48	.52
Loss on Ignition	1.34	2.19
Magnesium oxide	1.26	.50
Calcium oxide	95.33	92.00*
CaO Equivalents	96.59	70.00
Cost Price Del./Ton	$11.00	$10.00
Cost Price per ton CaO	$11.38	$14.28

*Calcium Hydroxide—$Ca(OH)_2$ or $CaO + H_2O$.

In Table No. 1, a typical analysis and price of calcium hydroxide as compared to calcium oxide shows the economic status of the two types of lime. In buying a typical pebble calcium oxide in place of calcium hydroxide, a net saving of $2.90 per ton of CaO equivalents is realized, plus higher operating efficiency. In actual plant operation the saving will be greater, since the theoretical ratio of one part CaO to 1.32 parts $Ca(OH)_2$ approaches a practical operating ratio of 1 part CaO to 1.5 parts $Ca(OH)_2$.

Another way to save money in buying quicklime is in the size of the lime. A pulverized calcium oxide (passing 200 mesh) is more costly than a standard pebble or cracked lime. The manufacturer must charge for the expensive process of pulverizing and will raise the price of calcium oxide from $11.00/ton to approximately $13.00/ton for the pulverized product. Also for large plants, the lime shipped in 15 ton cars costs more than in 25 ton cars, due to the freight rates.

With the money that can be saved by shifting from calcium hydroxide to pebble calcium oxide, an excellent feeder and slaker can be purchased and the lime treatment will become a controlled process rather than the usual "hit or miss" process. The operator should investigate and experiment with different types of lime to find the one best suited to his own plant and local conditions.

Lime Slaking Equipment and Its Operation

The operation of the slaker is not easy. Like a man learning to ride a bicycle, the problem looks simple yet requires initial research and a few hard knocks before the art is mastered.

First, and most essential, is an efficient dry-feeder. In the Richmond Filter Plant, an Omega lime feeder delivers the lime to the slaking vat at an astoundingly accurate rate. The feeder is a gravimetric batch type having a maximum capacity of 175 pound/hour and a minimum capacity of 1.75-pound/hour. The feeder has a 1,000 pound capacity, and properly designed hopper equipped with an agitator and mounted on a sensitive beam scale. The adjusting mechanism for changing the rate of feed is located in a compact unit with an alarm to indicate any trouble in feeding, such as an empty hopper or failure of material to leave the hopper. The lime feed is controlled by the vibrating plate at the bottom of the hopper. The pebble lime of size not exceeding ¾ inch size falls off the vibrating plate directly into a compact Omega Slaker located on the same floor with the feeder in a floor space of only 54 inch by 84 inch for both feeder and slaker. The unit is equipped with a water operated vapor removal system to collect dust and steam from the slaker. The water from this unit is not wasted, but is used as make-up water for the slaker or in conveying the lime to the

point of application. The slaker has a minimum retention period of 30 minutes at the maximum rate of feed and is agitated with a motor driven impeller so adjusted to give proper circulation in the chamber.

Temperature Control Important

The optimum temperature for slaking will vary both with the type of lime and the retention period in the slaker. The most efficient slaker temperature range is between 150° F. and 180° F.; above 180° F. the steam and vapor will overload the vapor removal equipment and cause corrosion of the slaker and feeder. In the Richmond plant, the optimum temperature is 160° F. using a pebble lime having a 96 per cent CaO content. In order to maintain this temperature in the shaker, with our incoming water varying between 33° F. and 85° F., an electric water heater of three No. M-240, 4,000 watt Chronolox immersion heaters was purchased for the job. The heaters are equipped with three-way switches for seasonal control and thermostats on each unit to supply makeup water at a uniform temperature regardless of the temperature of the incoming water. The heat of hydration of calcium oxide is 273 calories per gram. However, in slaking small quantities of lime some of this heat is lost and must be supplemented by heat from the make-up water.

Proper Water Ratio

In slaking lime, too little water gives a heavy slurry that is too thick to be agitated properly by the impeller, yet an excess of water increases the expense of heating make-up water and will dilute the lime so that maximum retention time in the slaker is materially reduced. Different brands of lime require variable quantities of water, but a slurry of the proper viscosity is usually obtained by a ratio range of 1 pound lime to 3 pounds water to a ratio of 1:4½. After a series of experiments at the Richmond plant, the ratio of 1:4 was adopted and gives excellent operating results.

To control the ratio, a standard water meter is connected in the supply line to the heater. The meter was geared so that the lowest dial actually reads 3 times the amount of water passing through the meter. For example, one cubic foot of water passing through the meter indicated three cubic feet on the dial. This method was devised to afford the operator a chance to check the water flow at low rates much more readily than with the regular meter dial. After checking the flow, the operator refers to a chart (see Table 2) showing the meter reading corresponding to each rate of lime feed for a ratio of 1:4, adjustment being made by the needle control valve if necessary. Example: Feed 50 lbs./hr. of lime. Requires for ratio 1:4, 50 × 4 or 200 lbs./hr. of water equals

$$\frac{200}{62.4} = 3.2 \text{ cu. ft. per hour of water.}$$

On special dial, this reads 3.2 × 3 or 9.6. On the chart opposite the rate of 50 lbs./hr. is the value 9.6 which should be the reading of the meter for one hour. The operator adjusts the valve to get this reading.

The lime after slaking is diluted with water from the vapor removal unit and flows over a weir into the outlet line. Some lime has considerable core so that the machine is designed for core removal, without stopping the slaker operation. The core is removed to a chamber to be washed to recover any calcium hydroxide on the surface and is then dumped into a trash can under the slaker. Tests are being run on the amount of unslaked lime in the sample collected at the effluent of the slaker but are not complete enough at present to report in this paper.

TABLE II

Water Meter Reading vs. Dial Setting for Optimum Ratio one lime to four water.

Pounds/hr. Lime	Dial Setting	Meter Reading (Cu. ft.*)
1.75	1	.3
8.75	5	1.6
17.50	10	3.4
26.25	15	5.0
35.00	20	6.7
43.75	25	8.4
52.50	30	10.0
61.25	35	11.7
70.00	40	13.5
78.75	45	15.1
87.50	50	16.7
96.25	55	18.4

*Special Meter Dial. Indicates three times actual flow.

Piping Lime Suspensions

No other problem seems more perplexing than that of transporting the lime to the point of application 300 feet or 400 feet from the slaker. If duplicate lines are available, one line can be cleaned with a chlorine solution while the other line is in service. However, caution must be observed to prevent the chlorine from actually attacking the iron pipe. Recently suggested is the use of "Calgon" to keep the lines free of incrustants but so far little work has been reported on this method. Many plants use rubber hose and clean the line by beating or shaking the hose. The author has found that the open trough is the simplest method of delivering the lime, provided the necessary fall between the machine and point of application can be obtained.

pH Control Simplified

So accurate is the control of pH with the new Omega slaker that in the Richmond plant we can hold a constant pH of 8.7 in our finished water. It is important to note in Table No. 3 that prior to the installation of the slaker, we had trouble in our distribution system with a decided drop in pH. Now with the present slaker we have only a slight drop and a corresponding decrease of iron in the dead-ends. We can only explain this by the fact that the controlled slaking is productive of a more highly peptized lime suspension—more nearly a colloidal suspension.

TABLE III

Station No. 34*
Location—Broad Rock Road

	Before Slaker Installation 1938	After Slaker Installation 1940
Res. Cl_2	.00	.00
Turb.	6.0	.80
Color	40	10
Alk. (M.)	23	36
Alk. (Phen.)	0	4.5
CO_2	0	0
pH	8.1	8.6
Fe_2O_3	4.0	.40

*This station is located near a dead-end.

It is hoped that water works men will study lime treatment and get more lime per dollar. Remember that often obsolete equipment can be scrapped and new equipment purchased with the saving, so why not have a modern plant at no extra cost?

ANHYDROUS AMMONIA

Its Storage, Feeding and Safe Handling

R. J. QUINN[1] and RALPH L. CARR[2]
The Mathieson Alkali Works, Inc., New York, N. Y.

IT is the purpose of this article to present some of the more significant physical and chemical properties of ammonia, together with information concerning the safe and efficient handling of ammonia and ammonia containers.

What Is Ammonia?

As distinguished from elemental gases such as chlorine, oxygen, nitrogen, etc., ammonia is a compound gas. It is composed of two gaseous elements, nitrogen and hydrogen, in the proportion of one part of nitrogen to three parts of hydrogen by volume—the formula being (NH_3). However, since one volume of nitrogen (as gas) weighs fourteen times as much as an equal volume of hydrogen, on a weight basis the proportions assume the relations of fourteen parts of nitrogen to three parts of hydrogen.

Ammonia was originally produced in commercial quantities solely as a by-product from the destructive distillation of coal in the manufacture of coal-gas and coke. Advances in science and technology coupled with increasing demands made other supplies available. Today, the most important production of ammonia is by means of the synthetic process which combines elemental nitrogen and hydrogen.

Since air consists of approximately 80 per cent nitrogen, almost 20 per cent oxygen, and minor quantities of other gases, the atmosphere serves as a limitless reservoir of nitrogen.

In the atmospheric synthetic ammonia process, nitrogen is separated by first liquefying air and then subjecting the liquid air to a fractional distillation. Thereby, nitrogen of very high purity is obtained.

The hydrogen necessary for reaction with nitrogen is obtained from several sources. In some instances water gas, which is largely a mixture of hydrogen and carbon monoxide, is used. The hydrogen is separated and purified by a number of different processes. Another source of hydrogen is the process of electrolyzing salt to produce caustic soda and chlorine. Hydrogen is one of the gaseous products from this reaction. Since it is relatively highly concentrated and carries few impurities, hydrogen from chlorine-caustic cells is readily brought to a condition satisfactory for the production of ammonia.

Nitrogen and hydrogen in a high state of purity when brought together in the presence of a suitable catalyst, under pressure and at elevated temperature, will combine to form ammonia. Refrigeration, compression and other common methods of gas separation and purification are used to bring the ammonia to a liquefied condition, suitable for commercial packaging and shipping.

Physical Properties of Ammonia

Liquid ammonia is a colorless, mobile and strongly refrigent liquid which boils at —28° F. (—33.35° C.) under atmospheric pressure. When the liquid is cooled to —107.86° F. (—77.7° C.) it solidifies to a white crystalline mass. At ordinary temperatures and pressures, of course, ammonia exists as a gas which is highly soluble in water.

Gaseous ammonia has a sharp, pungent odor. It is much lighter than air, having a density (with air as unity) of 0.5971 at standard conditions of temperature and pressure. Liquid ammonia, unlike liquid chlorine, is much lighter than water, having a density of 0.6234.

The following table presents the more important physical constants of ammonia:

Physical Constants of Ammonia

Molecular symbol	NH_3
Molecular weight	17.032
Boiling point (1 atmosphere, 760 mm. Hg)	—28° F. —33.35° C.
Freezing point (1 atmosphere, 760 mm. Hg)	—107.9° F. —77.7° C.
Critical temperature	270.3° F. 132.4° C.
Critical pressure	1,636 lbs./sq./in. (absolute)
Latent heat (at —33.35° C.)	326.9 cals.
Vapor density (air = 1)	0.5971
Vapor density (lbs./cu. ft.)	0.0446
Liquid density, at boiling point	0.6234 (water = 1)
Liquid density (lbs./cu. ft.)	42.56
Specific volume (cu. ft./lb.)	22.42

Since ammonia is a gas at ordinary temperatures and pressures, liquid ammonia has a definite vapor pressure which varies with temperature. This relationship is graphically shown in Fig. 1.

When liquid ammonia, confined in a cylinder, is heated, it expands with a consequent change in density; this change is shown in Fig. 2. If the temperature should reach 145° F. then the cylinder would be entirely full of liquid ammonia. Higher temperatures are considered dangerous because they may cause the cylinder to rupture, due to the establishment of hydrostatic pressure rather than gas pressure.

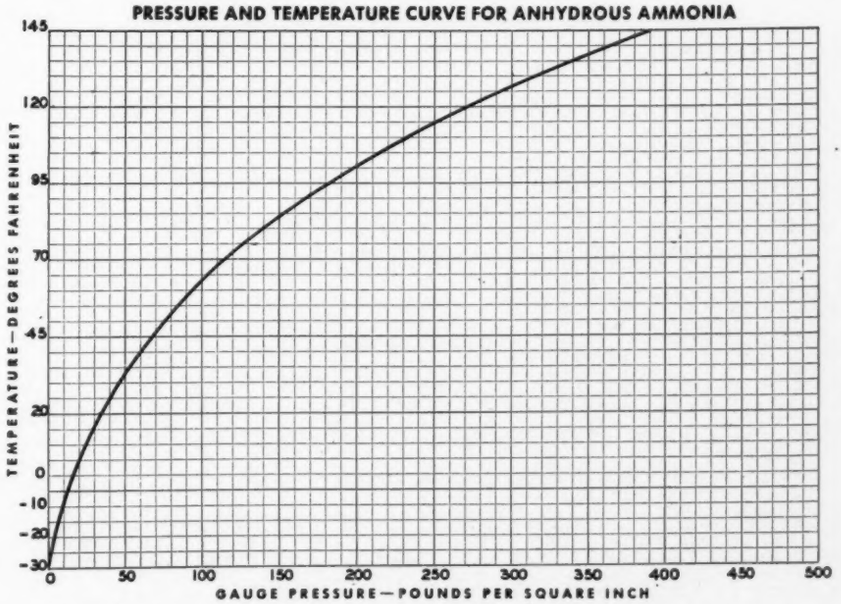


Fig. 1—Curve Which Reveals Pressure Changes in Ammonia Containers at Various Temperatures

(Note that at 72° F. the pressure is approximately 120 lbs. and only 50 lbs. at 32° F. At recommended limit of 110° F. the pressure mounts to 230 lbs./sq. in.)

[1]Director of Chlorine and Ammonia Sales.
[2]Technical Service Engineer.

Chemical Properties of Ammonia

Under normal conditions, ammonia is a very stable compound. It takes excessive temperatures (in the order of 1000° F.) to cause it to dissociate even slightly. When this happens the products are nitrogen and hydrogen. The gas will neither burn nor support combustion. However, air containing from 16 per cent to 27 per cent of ammonia represents an explosive mixture which can be exploded by sparking.

The common metals are not affected by dry ammonia. Moist ammonia will not corrode iron or steel but will rapidly react with silver, copper, brass, zinc, aluminum and many solders and alloys, especially those containing copper, zinc, or silver. It is thus evident that none of the latter materials should be employed for piping ammonia or ammonia water, whereas iron or steel is satisfactory.

Ammonia has a high affinity for water, reacting with it to form ammonium hydroxide (NH_4OH). Therefore, ammonia gas is highly soluble in water. At 32° F. one volume of water will dissolve 1,150 volumes of ammonia, or, on a weight basis, 47.3 per cent of ammonia gas (NH_3). Since the vapor pressure of ammonia increases with rising temperatures the solubility of ammonia in water should also decrease as the temperature rises. This is true, as is shown graphically in Figure 3. The high solubility of ammonia in water is of benefit in the design of ammoniators used in water treatment. In such machines the gas is dry-fed directly to the water supply through a diffuser, without the necessity of first preparing a water solution as is prevalently practiced in chlorination.

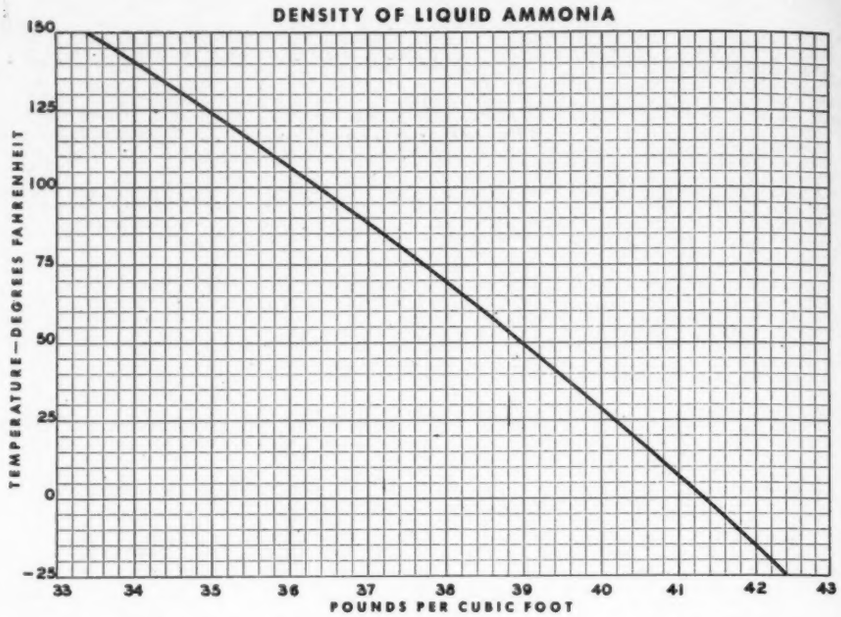


Fig. 2—Curve Revealing Effect of Temperature Rise in Increasing the Volume of Anhydrous Liquid Ammonia

(Should the temperature mount to 145° F. cylinders will be entirely full of liquid ammonia. This consideration stresses the dangers of high temperatures and the limitations imposed on quantity loading of containers at the factory. At 145° F. the pressure would be 390 lbs./sq. in., but the real danger is that full containers have to withstand hydrostatic pressures which bulge the cylinder walls which ends in eventual rupture.)

Ammonia Containers

Two general types of containers, tank cars and cylinders, have been accepted by the Bureau of Explosives of the Interstate Commerce Commission and by the Association of American Railroads as being suitable for shipping anhydrous liquid ammonia. The tank car is a single unit car, similar in appearance to that used for oil and liquid chlorine shipments. (As only a limited number of large scale consumers can handle this type of car, it is unnecessary to discuss this here.)

Cylinders used for shipping liquid ammonia are of two types: the tube-type illustrated in Fig. 4 and the so-called bottle-type shown in Fig. 5.

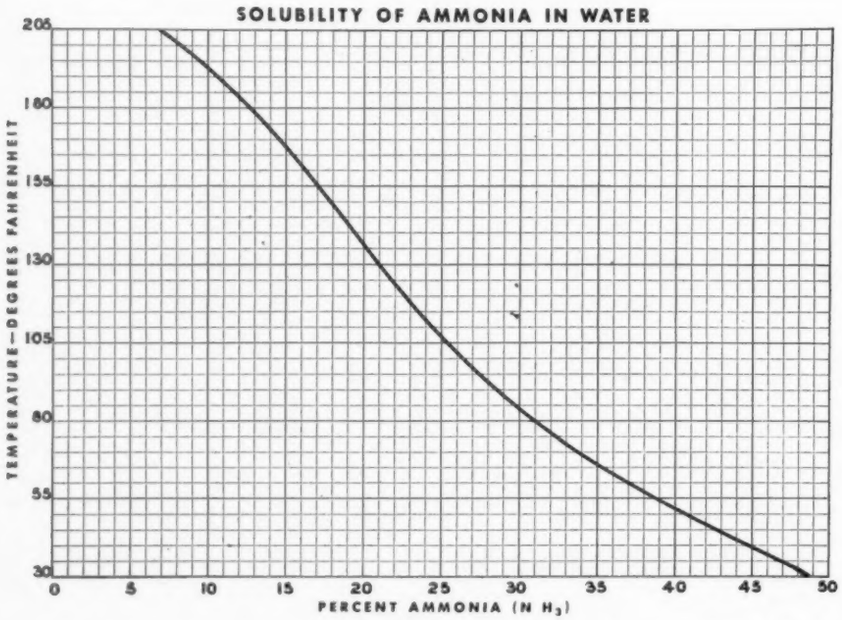


Fig. 3—Curve Revealing the Solubility Range of Ammonia Gas in Water at Various Temperatures

(The marked solubility of ammonia in water as compared to chlorine and other gases is revealed. At freezing temperature a saturated solution will contain 47.3 per cent of NH_3 gas by weight. Even at 100° F., water will carry better than 26 per cent NH_3 by weight.)

Tube-Type Cylinders

Tube-type cylinders are available in three sizes. They have capacities of 50, 100 and 150 pounds of ammonia—practically 100 per cent NH_3. The overall dimensions of these cylinders are shown in Fig. 4. The valves have a 37° standard ⅜-inch pipe cap outlet and are fitted with an internal dipper pipe. A dipper pipe is merely a pipe attached to the valve and extending inside the cylinder so that ammonia in liquid form may be withdrawn without turning the cylinder upside down. In water works practice we have never heard of this method of withdrawal being used. Consequently it is usually important to see that the dipper-pipe is pointing up when making connections. The average net and tare weights of these cylinders are also given in Fig. 4.

Bottle-Type Cylinders

The bottle-type cylinder illustrated in Fig. 5 has a 90° valve with a standard ⅜-inch recess pipe thread; it too has an internal dipper pipe. This container is of one size only and holds 100 pounds of ammonia. The dimensions of this cylinder and its average net and tare weight are also given in Fig. 5. Due to the fact that this cylinder, like chlorine cylinders, stands in a vertical position, it occupies a minimum amount of floor space and is, therefore, convenient for use where space is of primary importance. Also, the right-angle valve outlet, and the non-necessity of considering the position of the dipper-pipe,

makes connections to ammoniating apparatus an easy matter, requiring less attention.

Ammonia cylinders are made of steel, the specifications for the steel being rigidly outlined by the interstate Commerce Commission, and are regularly tested by the ammonia shipper to insure safety in use. The test consists of filling the cylinders with water, exerting a pressure of 700 pounds and measuring the amount of expansion. After this, the pressure is released and the cylinder is again measured to determine to what degree it may have been permanently distorted. If the permanent distortion is too great the cylinder is discarded.

Handling Ammonia

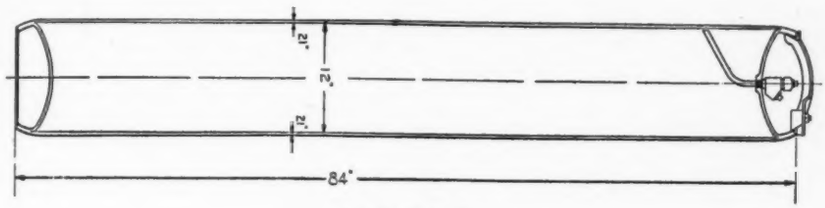
It is important, in the handling of ammonia, to recognize that it is a liquefied gas stored under pressure and that as such, containers should not be subjected to abnormal mechanical shocks and *temperatures should not exceed* 110° *F.*

Cylinders should be stored in a cool, dry place, preferably away from cylinders containing chlorine. Accidental leaks may permit mixing of chlorine and ammonia gases. When these two gases are mixed a dense white cloud of ammonium chloride is first formed; but if chlorine predominates in the mixture explosive *nitrogen trichloride may be formed.* If the two liquids happen to be mixed the resulting reaction may produce nitrogen trichloride and consequent explosion.

The room in which ammonia cylinders are stored and used should be equipped with an exhaust fan *located near the ceiling.* In case of a leak the ammonia, being lighter than air, will rise and be removed. (The reverse is true in the case of chlorine gas.) Bottle type cylinders should always be *stored upright.* Tube type cylinders should be stored horizontally, and blocked to prevent rolling.

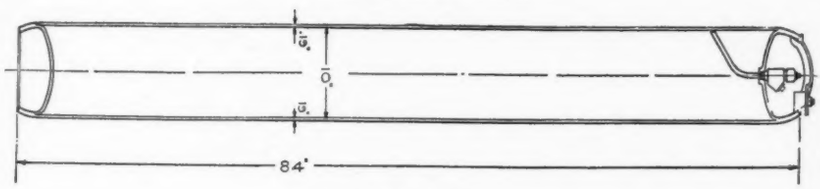
When not in use, valves should be protected by keeping caps in place. *Bottle type cylinders should never be lifted by passing a rope or chain through the cap slot,* as this may result in a broken or strained valve. If gaseous ammonia is to be withdrawn from the cylinders, they should be kept in the room housing the ammonia equipment for at least 24 hours before placing in use, in order that the contents may come to room temperature. If the ammonia gas is not at the same temperature as the ammoniating equipment, reliquefaction may take place in the feed line. This occurs only when the ammonia gas is warmer than the pipe line and some of the gas is liquefied by the chilling under the higher pressures.

Sectional Views of Cylinders



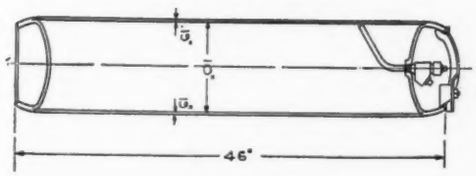
150-lb. Cylinder

Net wt. .. .. 150 lbs.
Tare wt., average 238 lbs. (Without Cap*)
Gross wt., average 388 lbs.



100-lb. Cylinder

Net wt..... 100 lbs.
Tare wt., average 165 lbs. (Without Cap*)
Gross wt., average 265 lbs.



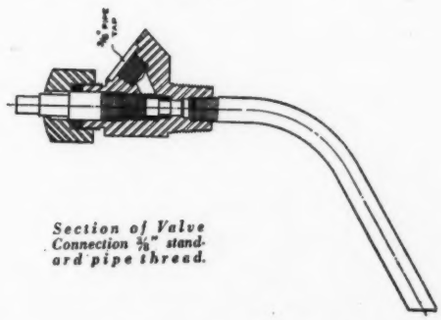
50-lb. Cylinder

Net wt..... 50 lbs.
Tare wt., average 102 lbs. (Without Cap*)
Gross wt., average 152 lbs.

**Average weight of caps*

for 150-lb. cylinder—6½ lbs.,

for 100 and 50-lb. cylinders—6 lbs.



Section of Valve Connection ¾" standard pipe thread.

Fig. 4—Dimensions, Capacities and Weights of Ammonia Cylinders of the Tube Type

(Usually in prone position when in service, but may be stood upright or in an inclined position.)

Withdrawing Ammonia

To withdraw liquid ammonia, both types of cylinders must be placed horizontally with the eduction pipe dipping into the liquid. To withdraw gas, the tube type must be turned so that the end of the dipper pipe is not in the liquid ammonia, or he cylinder may be stood at an angle or on end. The bottle type will of course deliver only gaseous ammonia when standing upright.

The packing gland nuts, on ammonia the cylinder may be stood at an angle or threads so that they will not "follow" the valve stem if the valve stem should adhere to the packing.

The amount of gaseous ammonia that can be withdrawn from any particular cylinder depends upon the surface area of liquid ammonia and upon the temperature of the air surrounding the cylinder. Thus it is obvious that the tube type cylinder, when in a horizontal position, will furnish more gas in a given time than the bottle type, other conditions being equal. The bottle type will discharge approximately 10 pounds per 24 hours, whereas the tube type will deliver at more than twice this rate—namely, 24 to 36 pounds per 24 hours, depending upon the size cylinder used. When greater quantities of ammonia are required a battery of cylinders may be connected to a single feed line.

Piping and Valves

Since moist ammonia will rapidly corrode copper and its alloys, valves and piping of these metals should never be used. The only permissible materials of construction are iron and steel. Piping may be of the extra heavy, rigid, steel type, or, in the case of short connections, of flexible steel. Screwed fittings may be used on temporary equipment, but flange, tongue and groove fittings, or ground joints should be used

on all permanent installations. When screwed fittings are used they should be made up with litharge and glylerin cement. With flange fittings use either lead or asbestos composition gaskets. Valves or pipe lines should be of the all-steel type, especially designed for use with ammonia.

Leaks

A leak in the ammonia valve, valve connections, ammonia feed lines and in the ammoniator connections generally indicates its presence by the characteristic odor of ammonia. The exact location of the leak in any of these places may be detected by holding an open bottle of hydrochloric acid near the suspected leak. A burning sulfur taper or moist phenolphthalein paper may be substituted for the hydrochloric acid bottle. When gaseous ammonia comes in contact with fumes or hydrochloric acid or fumes from a burning sulfur taper, a dense white fog is produced. Moist phenolphthalein paper will turn red due to the alkalinity of the ammonium hydroxide formed by the absorption of the ammonia in the moist paper. It is of course possible to substitute strong chlorine water for hydrochlorine acid in tracing leaks.

Only an authorized person familiar with the plant should attempt to stop a leak and if there is any question as to the seriousness of the leak, a gas mask should be worn. All persons not equipped with masks should leave the affected area until the leak has been investigated. The mask should be of the type approved by the U. S. Bureau of Mines for use with ammonia. It should be stored at the most convenient point where the atmosphere cannot become contaminated with ammonia. When a mask is not available, a cloth or spnoge soaked in water and held over the mouth and nose provides temporary protection.

When there is a leak around a valve stem, it can usually be corrected by tightening the packing gland nut. In case of serious cylinder leaks, such as leaks around the bottom of the valve, the cylinder should be removed to a point away from the building. If possible its contents should be discharged to the atmosphere where it will be rapidly dissipated. When a leak occurs in a congested area where atmospheric dissipation is not feasible, the ammonia should be absorbed in water. Fortunately this procedure is very simple and easily done because of the marked solubility of ammonia in water. Thus the ammonia may be saved by making a solution, or it may be wasted into a flowing sewer, as long as the gas enters beneath the surface of the sewage.

Flooding with a large volume of water from a hose will lessen vaporization as the vapor pressure of ammonia in water is much less than that of liquid ammonia. *Liquid ammonia should not be neutralized with acid—the heat generated by this reaction may increase the fumes.*

In case of fire every effort should be made to remove ammonia cylinders from the premises. If they cannot be removed then the firemen should be notified as to their location, because it must be recalled that optimum mixtures of air and ammonia (16 to 20 per cent NH_3) will create an explosion if ignited.

Physiologic Effects of Ammonia

Ammonia is not considered a poisonous gas, but due to its high solubility in water, it does have a very irritating action on the mucous membrane of the eyes, nose, throat and lungs. Fortunately, since its sharp, pungent odor serves as a warning signal, very small concentrations of ammonia in air are readily detected.

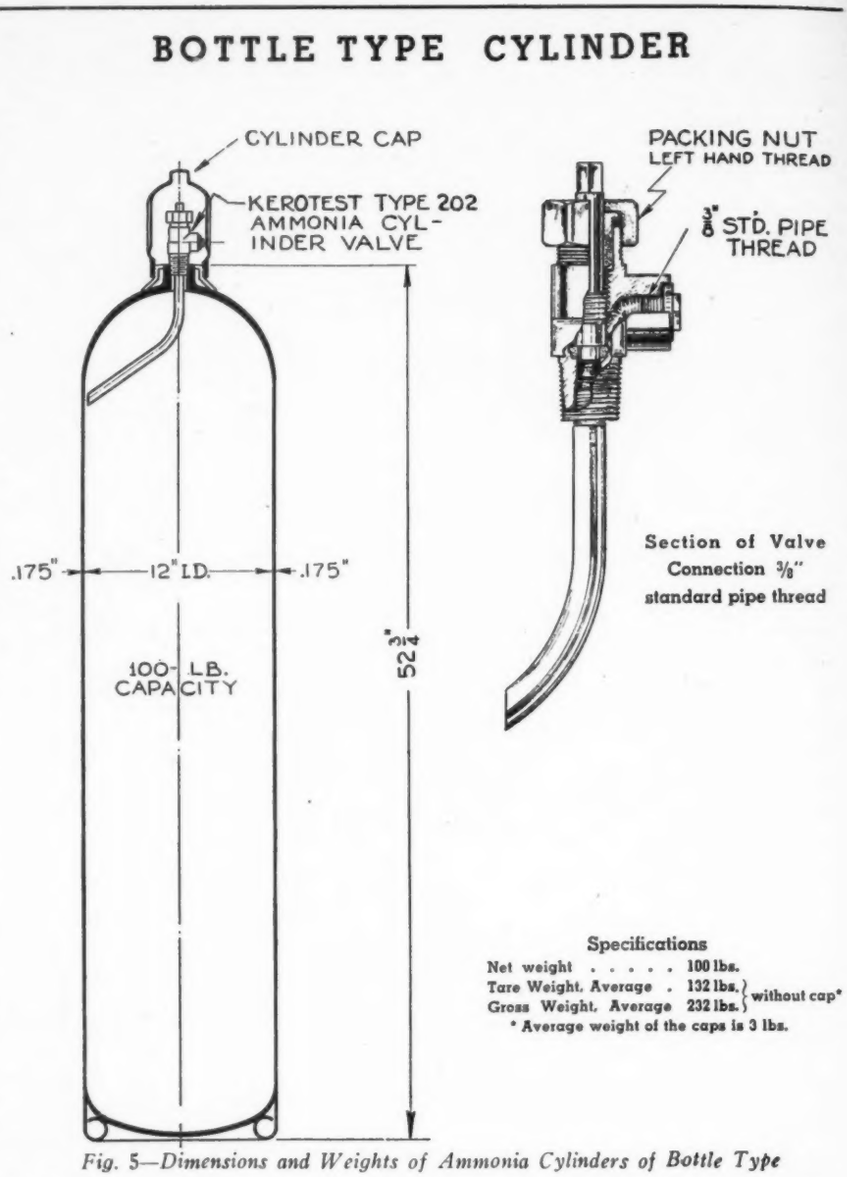

BOTTLE TYPE CYLINDER
CYLINDER CAP
KEROTEST TYPE 202 AMMONIA CYLINDER VALVE
PACKING NUT LEFT HAND THREAD
3/8" STD. PIPE THREAD
.175"
12" I.D.
.175"
52 3/4"
100- LB. CAPACITY
Section of Valve Connection 3/8" standard pipe thread
Specifications
Net weight . . . . . 100 lbs.
Tare Weight, Average . 132 lbs.
Gross Weight, Average 232 lbs.
without cap*
* Average weight of the caps is 3 lbs.

Fig. 5—Dimensions and Weights of Ammonia Cylinders of Bottle Type

(Available in 100 lb. capacity only. Always in upright position in service; has advantage of requiring less floor area, greater ease in handling, storing and placing in service.)

The following table shows the physiological response to various concentrations of ammonia in air. (Henderson and Haggard.)

	Parts of Ammonia Per Million Parts of Air (By Volume)
Least detectable odor	53
Maximum concentration allowable:	
(1) For prolonged exposure	100
(2) For short exposure (to one hour)	300–500
Least amount causing immediate irritation:	
(1) To the throat	408
(2) To the eyes	698
(3) Producing coughing	1720
Dangerous for even short exposure (½ hour)	2500–4500
Rapidly fatal for short exposure	5000 or more

Exposure to air containing small amounts of ammonia is not harmful, but breathing air containing from 5,000 to 10,000 p.p.m. of ammonia may cause sudden death from spasm or inflammation of the larynx. High concentrations of ammonia gas will cause severe irritation of the eyes and permanent injury may result if immediate remedial measures are not taken. Ammonia's high solubility in water causes it to irritate any skin surface where moisture has accumulated. The resulting NH_4OH is caustic but far milder than caustic soda, of course.

Since liquid ammonia vaporizes readily and has a great affinity for water, it may cause severe injury to the skin by both freezing the tissue and subjecting it to the caustic action mentioned. The symptoms of such a burn are practically the same as those of a thermal burn. The skin can withstand a 2 per cent ammonia solution, but greater concentrations have an intensely irritating action, especially on those portions of the body subject to perspiration.

First Aid

Any person who has been overcome or seriously injured by ammonia should receive the following "First aid" treatment:

1. *Pending the arrival of a physician.* Remove affected person to a place where there is fresh air. Place the patient flat on his back in relaxed position. Keep the patient quiet and warm. If necessary, prevent chilling by wrapping in blankets and warming with hot water bottles. The patient should be guarded against exposure to draft, especially if perspiring freely, and should not be excited or exercised unduly.
2. Call physician.
3. If patient is unconscious, use prone pressure (Schaeffer) method of artificial respiration. In the event that a police or fire department rescue squad is involved, make certain that a *pulmotor or other mechanical means of resuscitation is not applied.* The use of such equipment may rupture the lungs of the patient.
4. *Nose and Throat Burns:* Rinse out thoroughly with water, then use a 2 per cent boric acid solution to rinse mouth and snuff up nasal passages. Urge the patient to drink large amounts of water or milk.
5. *Eye Irritation:* Hold the lids open and pour water, then 2 per cent boric acid solution over the eyeball. After thorough rinsing in this way (at least 5 minutes) put two drops of liquid petrolatum in each eye.
6. *Skin Burns:* Remove ammonia-soaked clothing. Rinse thoroughly with water. *Light burns* may be swabbed with a solution of picric acid or carron oil. *If the burn is deep or sensitive picric acid* or carron oil should not be used. In such cases wash well with water, cover with boric acid compresses and keep moist until physician arrives. Recent medical research has shown that tannic acid is very efficient for treating burns and if desired, a freshly prepared 5% solution of tannic acid in sterile water may be used instead of boric acid for the compresses. The tannic acid solution should not be allowed to come in contact with the inner surfaces of the eyes as harmful results may follow.

All users of ammonia should have a first-aid cabinet containing the necessary supplies required to properly treat ammonia injuries. Posted on the cabinet should be the names of various physicians with their addresses and telephone numbers.

Summary (Some Dos and Don'ts)

1. Handle cylinders carefully. Do not drop.
2. Cylinders should be stored in a cool dry place away from sources of heat and protected from continued dampness. Storage near radiators or steam pipes may raise the pressure of the gas to a dangerous point while dampness may cause excessive corrosion.
3. Keep cylinder caps and valve plugs in place when cylinders are not in use.
4. Weigh cylinders, including caps, before connecting and check this weight against the gross weight shown on tag.
5. Open valve slowly and *only with the special wrench provided.* (Before opening valve, read instruction tag attached.)
6. Keep ammonia gas mask available for individual authorized to act in cases of emergency.
7. In case of leaks, remember that gaseous ammonia is lighter than air and rises. Also, that it is very soluble in water.
8. Cylinders should not be exposed to temperatures exceeding 110° F.
9. Use extra heavy steel piping and ammonia valves for service lines. Copper and copper alloys should *not* be used.
10. Persons overcome by ammonia should be removed from the affected area, kept warm and given first aid treatment pending the arrival of a physician.

SOLVING CHLORINE ICE TROUBLE

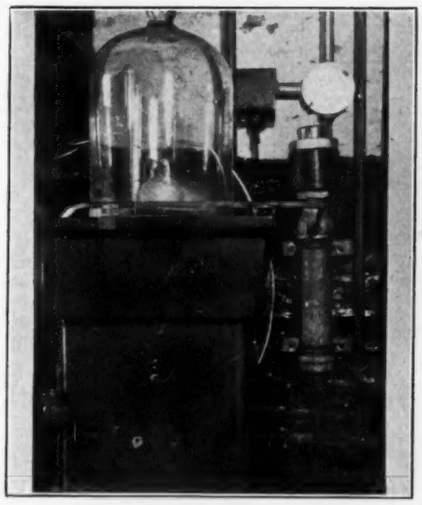
By DON CALDERWOOD, Engr.
Pennichuck Water Works Co.
Nashua, N. H.

IF you have had trouble with chlorine hydrate—usually called chlorine ice—forming in your chlorinator, you may be interested in hearing how we solved this problem.

A few years ago we purchased a Wallace & Tiernan type MCVM chlorinator. The following winter we experienced our first real trouble with so-called chlorine ice. We built a wooden box over the bell jar and put electric lights in it; we tried a unit from a sun bowl heater inside the standard under the tray; and then a combination of both. These gave results after a fashion but did not do a real workmanlike job—so after three or four seasons of makeshift operation we set out to find a permanent solution to the problem.

We purchased a 1,500 watt immersion heater with a three heat switch giving us 500, 1,000, or 1,500 watts as needed. We then took a piece of 2½ inch pipe about 10 inches long, screwed a cap on one end, a reducing coupling on the other, and into the reducing coupling we screwed the 1,500 watt heater. We next tapped into the cap and coupling for ⅛ inch copper tubing and after fastening the assembled unit to the chlorinator we disconnected the water supply line to the tray and with copper tubing made new connections so that all the water going into the tray first passed through the heating unit. To eliminate the possibility of forgetting to turn the heat either on or off, we purchased a pressure switch and connected it to the water supply line in such a way that it automatically turns the current for the heating unit on when we turn on the water supply to the chlorinator, and also turns it off when the water pressure is shut off.

This scheme worked perfectly for about three winters and then a ground started to show on our switchboard. We traced it to the heater and found that in our zeal for efficiency and in our desire to utilize all the heat available we installed the heater with the electric connections pointing down. During the humid summer weather condensation from the outside of the pipe had run down on the electric connections finally causing the ground. We have now reversed the unit, putting the heater in from the top and expect no more trouble. We find that low heat, or 500 watts, is all the current we need to use except for a few days during the coldest part of the winter.



Our First Heater
(With Automatic Cut-off.)

This heating unit worked so well that we decided to put one on the chlorinator in our other station even though we use that station very little in the cold weather. This chlorinator was an older model and did not have a separate valve and line for the tray water supply, so we connected the heater similar to the other installation but conveyed the warm weather from the heater directly over the top and into the tray. The water supply was adjusted so that the water flowing through the heater and into the tray was just a little less than the required amount, the remainder being supplied in the usual way through the float valve in the tray supply line. Here are pictures of the original upside-down job and the trouble free improved job on the second chlorinator.

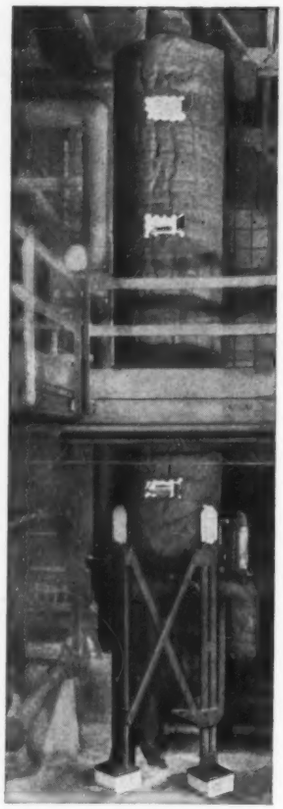
PENNSYLVANIA SALT MANUFACTURING COMPANY

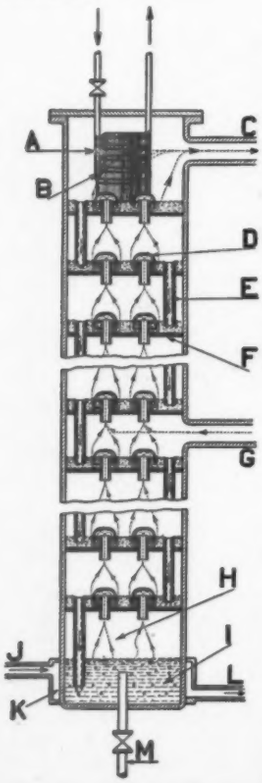
1047 WIDENER BUILDING, PHILADELPHIA, PA.

NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • WYANDOTTE • TACOMA

• LIQUID CHLORINE

A clean amber-colored liquid about one and one-half times as heavy as water. Supplied in steel containers which are under pressure at temperatures above 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being about 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is about two and one-half times as heavy as air. It is non-inflammable, non-explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.





Operating Diagram of the Chlorine Fractionating Column

A. Refrigerating Coil
B. Condensing purified chlorine
C. Purified chlorine outlet
D. Bubble cap
E. Downtake for reflux
F. Tray or plate
G. Raw chlorine inlet
H. Chloroform vapors
I. Chloroform and dissolved impurities
J. Steam inlet
K. Heating jacket
L. Condensed water
M. Drain for impurities

Chlorine has been proved to be the most efficient, flexible and economical agent for sterilizing water supplies; and it is also used as a sludge stabilizer, a taste and odor eliminator, a precipitating aid, and, in sewage treatment, for disinfection, for B.O.D. reduction and odor control. The quantity of chlorine required in water purification and sewage treatment processes depends upon the quality of water, the point of application, and the object desired. Penn Salt Liquid Chlorine is particularly adapted for such processes because of its high purity and freedom from objectionable "taffy" or chlorine gum, achieved by means of the specially designed Penn Salt fractionating column which eliminates practically all harmful impurities from the chlorine.

This Liquid Chlorine is supplied in seamless steel cylinders in sizes ranging from 10-lb. net to 150-lb. net. They comply with requirements of the Interstate Commerce Commission concerning specifications, retesting, loading, maintenance. Liquid Chlorine is also shipped in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes, 32,000 and 60,000-lb. respectively. The care with which all Pennsylvania Salt packages are cleaned and double-checked, coupled with the quality of Penn Salt Liquid Chlorine, assure maximum safety and convenience in chlorinator operation.

• PERCHLORON

Perchloron is a high strength calcium hypochlorite, having a guaranteed active ingredient of not less than 70% calcium hypochlorite or available chlorine. It is dustless, free flowing, concentrated and retains its labeled strength for one year or more under normal storage conditions. It weighs approximately 52.5 pounds per cubic foot. It is composed of finely divided particles, all of which will pass a 20 mesh screen and be retained on a 65 mesh screen. It is quickly soluble in water, and is useful as a second line of defense for water purification in cases of emergency, when supplies of liquid chlorine may be temporarily cut off. Perchloron is also used for sterilizing new mains, as well as clear wells and filters; valuable for sewage treatment, too. Many leading swimming pools sanitize their water with Perchloron, use it to combat slime and algae growths, and to control athlete's foot by means of trays and spraying locker and washrooms. Perchloron is supplied in handy-sized cans equipped with Kork-N-Seal covers, 9—5-lb. cans to the case. Also in 100-lb. drums.

● AMMONIA, Anhydrous

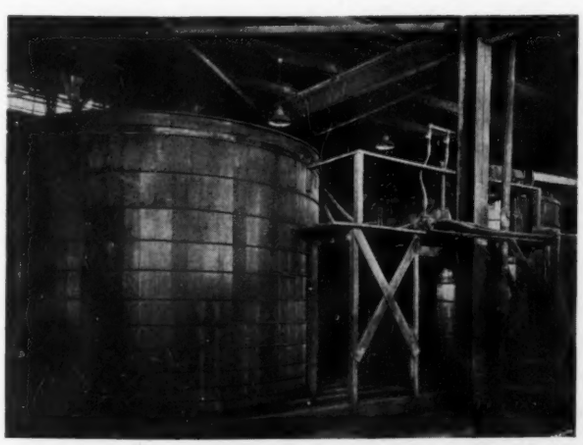
A colorless liquid which at 70° F. is 0.61 times as heavy as water, and weighs 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F., 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

This characteristic of ammonia is utilized in the dry feed ammoniators in water works. It is also useful in the chloramine process, in which ammonia is applied along with chlorine to prevent the formation of chlorinous, phenolic or medicinal tastes; and for stabilizing or prolonging the sterilizing action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, with points of application ranging over the entire purification process. To prevent taste intensification, the ammonia must be applied before the chlorine.

Pennsylvania Salt Anhydrous Ammonia is supplied in special improved cylinders of seamless drawn steel which are light, strong and easy to handle and store. Gas may be withdrawn either with a cylinder standing upright on a scale for weighing, or with the cylinder lying horizontal, whichever is most convenient.

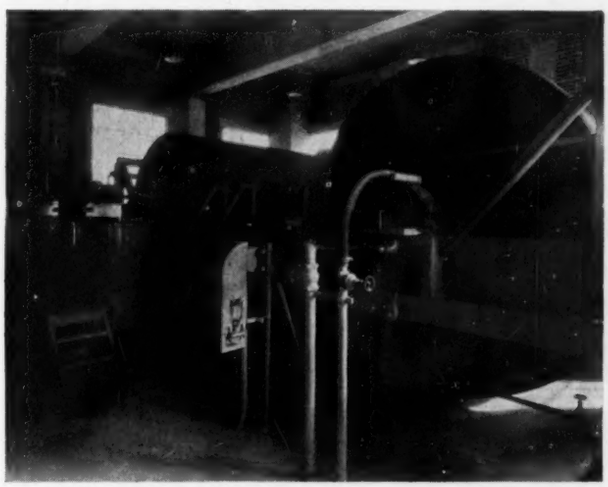
● FILTER ALUM (Sulphate of Alumina)

This product is the principal coagulant used in water purification; and Penn Salt Filter Alum has been adopted by many water works superintendents and engineers. Available in any quantity from a single bag or barrel to carload lots. Bags and barrels are paper lined as a protection against atmospheric moisture.



● FERRIC CHLORIDE

In liquid form it is an aqueous solution, the concentration of which is governed by the outside temperature and varies from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Pennsylvania Salt also supplies ferric chloride in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as is permitted by impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most communities, depending upon shipping costs, ferric chloride offers vast savings over alum. The aqueous solution is shipped in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. Anhydrous ferric chloride is shipped in non-returnable steel drums, 150 and 400 lb. sizes.



● SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda, used both for softening water and as a combined coagulant and softener. Most effective in water requiring an alkali with the alum. Shipped in thin steel non-returnable drums, net weight 100 and 400 lb. each; and in 100-lb. moisture-proof burlap bags.

● SODA ASH
CHLORIDE OF LIME, and
CAUSTIC SODA

are among the other chemicals made by Pennsylvania Salt and used in water purification and sewage treatment. Ask us for detailed information and expert technical assistance.

LIQUID CHLORINE*

Properties of Chlorine

Chlorine is never found free in nature. Gaseous chlorine is manufactured by the electrolysis of a sodium chloride solution. It is then purified and liquefied by a process of compression and refrigeration. As an article of commerce, chlorine is an amber-colored liquid approximately one and one-half times as heavy as water. It is marketed in steel containers which are under pressure. In Fig. 1 is shown the relation between temperature and vapor pressure.

When the pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times as heavy as air. Chlorine is non-inflammable, non-explosive, and a non-conductor of electricity. Generally speaking, in the absence of moisture it is not corrosive to common metals. In the presence of moisture gaseous chlorine reacts avidly with a majority of known substances.

Following is listed the more important chemical and physical properties of chlorine at standard conditions (32° F. and 1 atm. pressure) unless otherwise noted:

	Atomic	Molecular
Chemical Symbol for Chlorine....	Cl	Cl_2
Chemical Weight Relationship...	35.457	70.914
	Gaseous Chlorine	Liquid Chlorine
Specific Gravity	2.49* (air = 1)	1.47† (water = 1)
Weight per Cubic Foot...	0.201 lb.	91.70 lb.
Volume per Pound	4.98 cu. ft.	0.011 cu. ft.
Specific Heat		0.2230†
Liquefying Point		— 28.5° F.†
Freezing Point		—151.6° F.‡
Latent Heat of Evaporation		121.0 B.t.u.†
Critical Temperature		294.8° F.†
Pressure at Critical Temperature		1233 lb. per sq. in.
1 Volume Liquid		456 vol. gas

*Leduc †Kneitsch ‡Lange

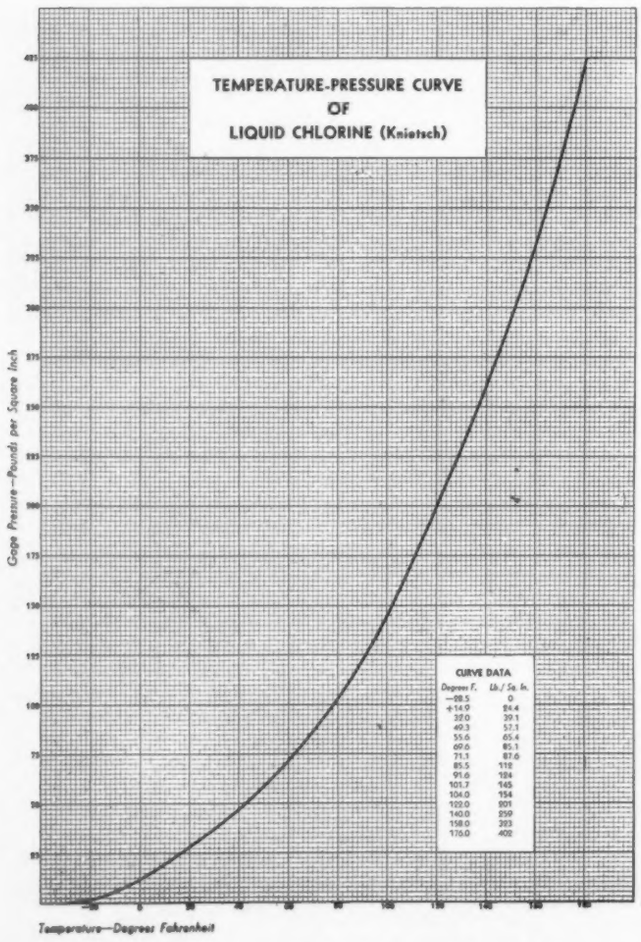


Fig. 1—Relation between Temperature and Vapor Pressure

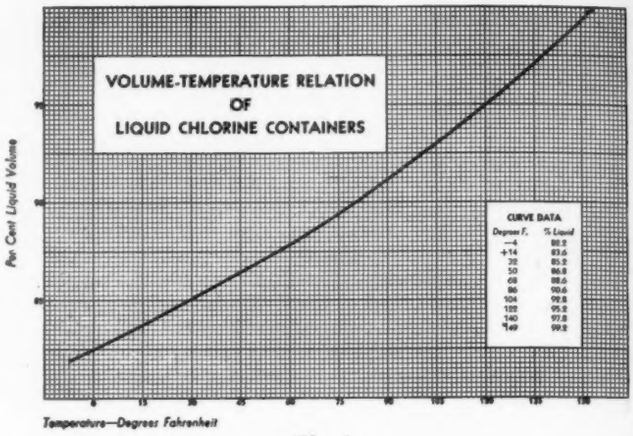


Fig. 3

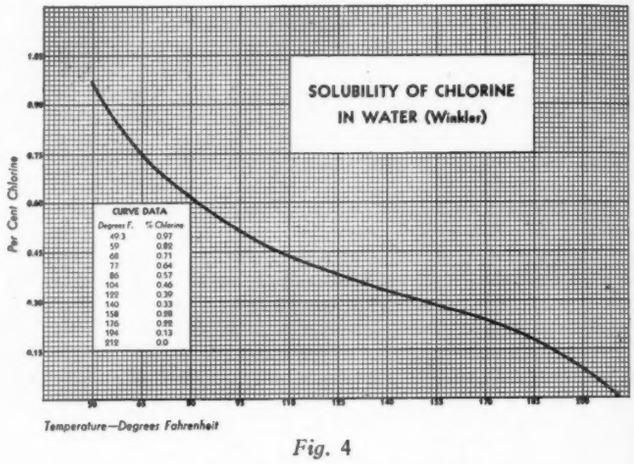


Fig. 4

A better visualization of those properties which are more serviceable can be obtained by studying the following charts and tables.

The compressibility coefficient of liquid chlorine is more than that of any other liquid element (approximately 0.0118% vol. /atm.). Its density decreases quite rapidly with increasing temperature. It is obvious from an examination of Figure 3 that above 156° F. a cylinder loaded to legal limits is subjected to hydrostatic pressure which will rupture it. Therefore, it is most important that the cylinder be kept safely below this temperature in any circumstances.

Chlorine is only slightly soluble in water. As depicted by Figure 4, its maximum solubility in distilled water is approximately 1% at 49.2° F. Below that temperature chlorine crystallizes in the form of chlorine hydrates, their composition depending upon conditions.

Liquid Chlorine Containers

Cylinders

Cylinders for shipping liquid chlorine by express, less carload, or box carload freight, are of various sizes ranging from 10 pounds net to 150 pounds net.

WEIGHTS OF 100 AND 150-LB. CYLINDERS

Net Contents	100 pounds	150 pounds
Average Tare Weight	93 pounds	123 pounds
Average Gross Weight	193 pounds	273 pounds

Minimum carloads comprise one hundred and fifty 100-pound cylinders or one hundred and eleven 150-pound cylinders.

Figure 6 illustrates the standard chlorine cylinder valve designed by the Chlorine Institute and now used by nearly all chlorine shippers. The stem "A" is of Monel metal and one complete turn in a counter-clockwise direction opens the valve so as to permit the maximum discharge of gas. A "frozen"

*From a bulletin on "Liquid Chlorine," prepared and distributed by Pennsylvania Salt Mfg. Co., March, 1936.
*From "Liquid Chlorine," a Pennsylvania Salt Mfg. Co. bulletin.

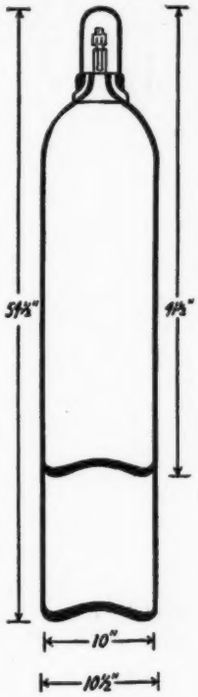
stem can usually be freed by slightly loosening the packing nut "C," tapping the top of the stem lightly, and then giving the valve wrench a sharp rap with the palm of the hand. The body "B" is a bronze and all connections to it are tightened by turning in a clockwise direction. Gas leaks around the stem can be checked by tightening the packing nut. *Under no circumstances tamper with safety plug "D."* It is below the valve seat and, therefore, cannot be controlled by the valve. Fusible metal in this plug softens at temperatures exceeding 157° F., hence cylinders should never be exposed to such temperatures for even short durations.

The valve outlet threads are standard ¾-inch hose coupling to which an auxiliary valve (containing a fiber or lead gasket) may be connected. However, these threads are bronze and are easily damaged. The clamp and adaptor shown in Figure 7 is the more practical type of connection.

Handling Cylinders

The handling of cylinders requires no expensive equipment. It is preferable that they be transported and stored in an upright position. Light, rubber-tired, two-wheeled trucks are convenient for moving them on level floors. Where cylinders have to be lifted above the ground floor a crane, or hoist, equipped with a special cradle, or carrier, should be provided in the absence of an elevator.

The maximum discharge rate of chlorine gas at 70° F. is approximately 35 pounds per 24 hours for a 100- and 150-pound cylinder. This rate may be increased by improving the circulation of air around the cylinder, or by raising the temperature. Under no circumstances should the application of heat be made directly to the fusible plug. The practical method of heating cylinders is by means of a thermostatically controlled water bath in which the temperature is limited to 100° F. Even this procedure is questionable if used in conjunction with a chlorinator because uneven temperatures prevail which in turn cause condensation difficulties. Where chlorine is used in equipment operating under cylinder pressures, it is essential that the cylinder temperature be no higher than that of the gas lines or chlorinator. Otherwise condensation will certainly occur with attending operating irregularities. (See Fig. 9.)



Cross Section of 100- and 150-Pound Cylinders

Fig. 5—Various Sizes of Cylinders

As soon as the cylinder is emptied, suction is set up tending to draw water and foreign matter back into the cylinder. This has caused several cylinder failures which could have been avoided by closing the cylinder valve as soon as the cylinder is empty.

Multiple Unit Tank Cars—Ton Containers

The multiple unit tank car is adapted for large chlorine consumers who desire a more flexible unit than the standard chlorine tank car. It consists of an underframe carrying 15 one-ton drums. Classed as a tank car, the underframe and units are subject to free freight movement both ways, freight being assessed only on the net contents of the car.

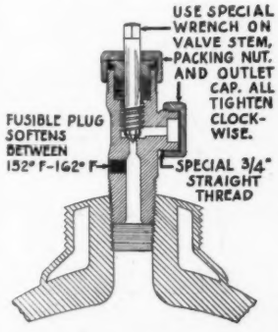

USE SPECIAL WRENCH ON VALVE STEM, PACKING NUT, AND OUTLET CAP. ALL TIGHTEN CLOCKWISE.
FUSIBLE PLUG SOFTENS BETWEEN 152° F-162° F.
SPECIAL 3/4" STRAIGHT THREAD

Fig. 6—Cross Section of Standard Cylinder Valve

Each of the unit containers holds 2000 pounds of chlorine. *This shipping container is authorized by the Interstate Commerce Commission for common carrier movement only as an integral part of a fifteen unit car. Multiple unit and tank cars may be consigned only to private sidings, or to approved public sidings.* (*Par.* 431*B I. C. C., Regulations as amended* 1933.) Where unloading conditions are ideal it is a useful package of chlorine because its units are of such size as to permit reasonable movability yet not requiring the frequent changing necessary when using small cylinders.

Each container is equipped with 2 valves, 2 internal eduction pipes, 3 fusible (157° F.) safety plugs in each end, and a removable valve hood. The valves are identical with the standard cylinder valves, except they are provided with larger internal valve openings and are not fitted with safety plugs.

Multiple unit tank cars are not recommended for plants using less than 200 pounds of chlorine per day.

Handling Ton Containers

Due to the size and weight of ton containers, special equipment is required for unloading and transporting to storage or service rooms. Stationary or movable cranes, travelling overhead rail hoists, trucks, and dollies have been employed to meet the peculiar needs of individual plants. Some type of lifting rig is necessary for use with cranes or hoists.

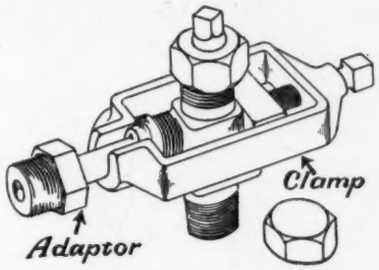


Fig. 7—Clamp and Adapter

Containers are more easily handled and serviced from a prone position. Before servicing the container should be rolled or adjusted so one valve is directly above the other as shown in Figure 12. In this position, liquid chlorine may be discharged from the bottom valve and gaseous chlorine from the top valve. Some plants concerned only with the application of gaseous chlorine prefer to up-end the containers for storing and servicing, which procedure produces material saving in floor space.

The clamp and adaptor connection previously illustrated is recommended as the most practical and flexible connection for container valves. Wrenches for operating these valves should never be longer than seven inches.

Four hundred and twenty pounds per 24 hours is approximately the maximum rate of gas withdrawal for a ton-container at 70° F., operating against 35 pounds per square inch back pressure. This rate may be increased by improving the air circulation around the container, or by raising the room temperature. *Ton containers should never be subjected to the direct application of heat because of the danger of melting the fusible plugs.*

Single Unit Tank Cars

Single unit chlorine tank cars are of two sizes, holding approximately 32,000 and 60,000 pounds of chlorine each. Located in the dome are two liquid withdrawal valves on the longitudinal axis, two gas valves on the transverse axis, and a safety valve. Each liquid eduction pipe is fitted with a vertically acting ball check which stops the flow of liquid chlorine from the car in case of unloading line breakage, sudden opening of valve, or very heavy withdrawal rates.

The withdrawal of gaseous chlorine from any liquid chlorine container causes refrigeration and subsequent pressure reduction in the container. This effect is markedly increased by the cork insulation on single unit tank cars, and consumers purchasing their chlorine requirements in single unit tank cars may find it necessary to use liquid chlorine vaporizers on their operation requiring chlorine gas. Vaporizers usually employ hot water or steam as their heat sources, and may be equipped with either open or closed jackets.

Piping and Fixtures

A copper tubing built for 500 pounds per square inch working pressure is the preferred material for connecting all chlorine containers to permanent pipe lines.

Dry Chlorine

Black iron pipe is recommended as the preferable material for dry gaseous or liquid chlorine, although steel, copper, or other metal piping which will resist high pressures may be used. While standard weight pipe is satisfactory for all normal chlo-

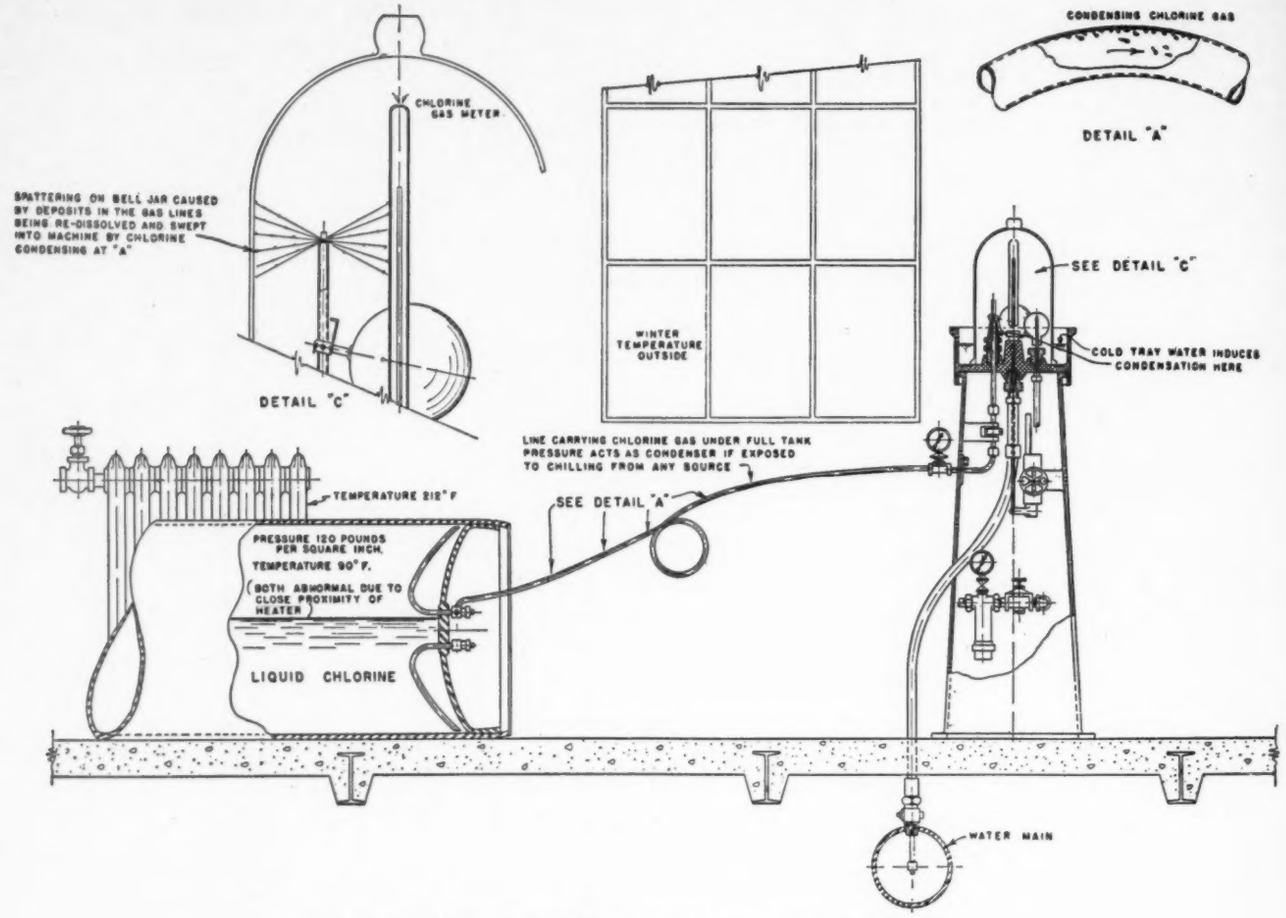

CONDENSING CHLORINE GAS
DETAIL "A"
CHLORINE GAS METER
SPATTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO MACHINE BY CHLORINE CONDENSING AT "A"
DETAIL "C"
WINTER TEMPERATURE OUTSIDE
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE ACTS AS CONDENSER IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
TEMPERATURE 212° F
PRESSURE 120 POUNDS PER SQUARE INCH. TEMPERATURE 90° F. (BOTH ABNORMAL DUE TO CLOSE PROXIMITY OF HEATER)
LIQUID CHLORINE
WATER MAIN

Fig. 9—Condensation Difficulties Caused by Uneven Temperatures

rine pressures, the extra heavy variety is recommended as safer and more practical since abnormal temperatures caused by fires, mechanical strains due to displacements, and corrosion produced by the entrance of moisture are all factors which should be considered. Liquid chlorine lines should be as free from bends and obstructions as possible. Where maximum discharge rates or lifts are required, pipe friction losses should be reduced by using lines of ¾ inch or more in diameter.

Hard rubber pipe is satisfactory for chlorine gas, but should never be used for conveying liquid chlorine. Pressure should not exceed 50 pounds and 80 pounds for the standard and extra heavy hard rubber pipe respectively. *Lines conveying gaseous chlorine should be run on a continuous upgrade in order that condensed (re-liquefied) chlorine will run back into the container.* Where this is impractical, drip legs should be provided in the low points of the pipe line. These legs should terminate in pockets which will assure evaporation of the liquid chlorine. *Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary.*

Pipe joints may be made with standard couplings, unions, or flanges. Standard ammonia flanges are preferable, since their use permits easy inspection and repair to lines. Gaskets should be of lead or asbestos composition. Only special valves for chlorine service should be employed. Usually, the body is of steel or special bronze, and the stem is of Monel metal. Graphite coated asbestos and rubber covered asbestos are recommended for packing. Flanged valves are preferable. Gauges should be of the diaphragm type for chlorine service. *Equipment and lines carrying dry chlorine should not be exposed to excessive heat.*

Wet Chlorine

Wet chlorine is very corrosive to all of the common metals. Materials contacting it must be of earthenware, glass, rubber, one of the special alloys, or noble metals. The handling of wet chlorine is an individual plant problem and specific recommendations can be made only after a survey and study of the various factors involved.

Employee Protection

1. Every person whose duties may cause exposure to chlorine should be provided with a gas mask of a design approved by the U. S. Bureau of Mines for chlorine service. Any canister gas mask is unsafe when chlorine concentration in the air exceeds one per cent (1%) or when the oxygen content is less than sixteen per cent (16%) by volume. In such cases oxygen breathing apparatus is required.
2. Individual gas masks should be provided and spare gas masks and canisters available in case of emergency. Complete familiarity with the mask and its maintenance is essential. A BAD GAS MASK IS WORSE THAN NO GAS MASK.
3. Periodic strict inspection and maintenance of approved gas masks are essential. Frequent drills in the use of gas masks are advisable.
4. Daily inspection of all loaded cylinders, ton containers, or tank cars is advisable in order to avoid developing a major leak. A small leak detected in its early stages can usually be stopped by immediate attention.

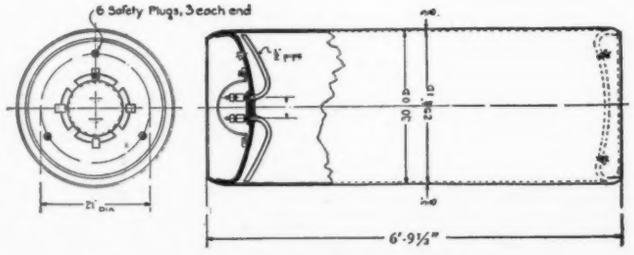


Fig. 12—Cross Section of a Ton Container

Leaks

5. When the odor of chlorine indicates a leak, authorized persons equipped with gas masks should immediately investigate. All other persons should leave the affected area.
6. Locating Leaks—Wrap a rag on a stick and soak it in ammonia water and swab the suspected points. A white smoke will show the point of leak.
7. Stopping Leaks—Shut off the chlorine supply if the leak is found in the pipe or equipment. All chlorine container valves close clockwise.
8. If the container leaks, move it outdoors or, in the case of a tank car, to the point on the consumer's private tracks where it will do the least harm. Leaking containers and tank cars will not be accepted by railroads or other carriers for shipment.
9. Leaks around valve stems may be stopped by tightening packing nuts. All standard chlorine valve packing nuts tighten clockwise. The construction of the valves is shown on this sheet.
10. Keep the head high (chlorine is heavier than air and seeks the lowest possible level). Keep to the windward side of a leak.
11. All leaks may be lessened by lowering the pressure in the container by withdrawing chlorine gas as rapidly as possible. If the consumer's process will not take the gas rapidly enough, an absorber may be made quickly in a barrel or suitable tank by dissolving 25 pounds of flake or solid caustic soda in 10 gallons of water. One and one-quarter pounds of caustic soda will be needed for each pound of chlorine absorbed. The chlorine gas is passed into the solution through a rubber hose or iron pipe.
12. Water played on a chlorine leak will not stop the leak. Water played on a leaking tank car always makes the leak worse, it will never dimish it.

What to Do in Case of Accidents

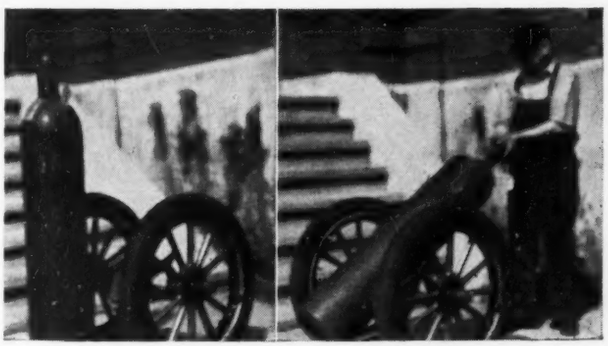
13. Carry patient from gas area. Patient should preferably be kept in a room at about 70° F. Supply blankets if necessary. Keep patient warm and quiet. Rest is essential.
14. Place patient on back with head and back elevated.
15. Call the physician immediately.
16. Splashes of liquid chlorine and chlorinated water destroy clothing, and if such clothing is next to the skin will provide irritation and acid burns. In such cases remove clothes and keep patient warm with blankets.
17. Give carbon dioxide and oxygen mixture which does not exceed 7% carbon dioxide. This mixture, already prepared, and sold with the necessary apparatus, can be administered intermittently for periods of two minutes followed by a two-minute rest over a total period not to exceed thirty minutes. Instructions of the purveyor of the gas apparatus should be carefully obeyed.
18. Milk may be given in mild cases as a relief from throat irritation.
19. If breathing has apparently ceased, start immediately the artificial prone pressure method of resuscitation (Shafer). Do not exceed 18 movements per minute.
20. Provide first aid as may have been prescribed for emergencies by your company physician pending his arrival.

Safety Cylinder Handling Carriage

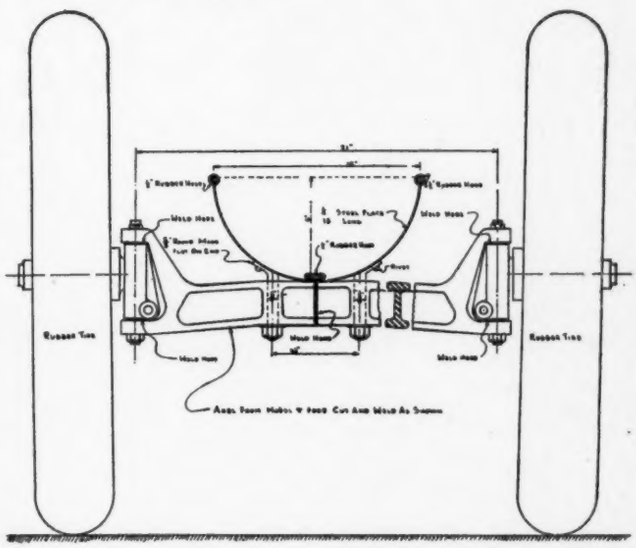
The accompanying pictures and detail sketch illustrate a novel, efficient and inexpensive carriage for transport of cylinders containing chlorine, ammonia or other compressed gases.

The device was designed and constructed from the wheels and front axle of what was once a Model "T" Ford automobile. Its ease of handling is self evident and its use saves many a "weak back" and avoids dangers of injury to the "strong men" around water and sewage plants.

To Edward J. Jenkins of the Philadelphia Suburban Water Company, Bryn Mawr, Pa., we are indebted for the illustrations of this unique cylinder truck which was developed in the above plant under his supervision.



In Position *Ready to Ride*



Model "T" Cylinder Carriage

Unique Carriage Designed for Cylinder Handling at the Water Purification Plant of the Philadelphia Suburban Water Co.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, etc.

NEWARK, NEW JERSEY

"The Only Safe Water Is a Sterilized Water"

Albany · Atlanta · Boston · Bridgeport · Buffalo · Charlotte · Chicago · Cleveland · Columbus · Dallas · Denver · Detroit · Greensboro · Houston · Indianapolis · Jacksonville · Kansas City · Knoxville · Lexington · Los Angeles · Madison · Minneapolis · Oklahoma City · Omaha · Philadelphia · Pittsburgh · Roanoke · San Francisco · Seattle · St. Louis · Syracuse · Washington, D. C.

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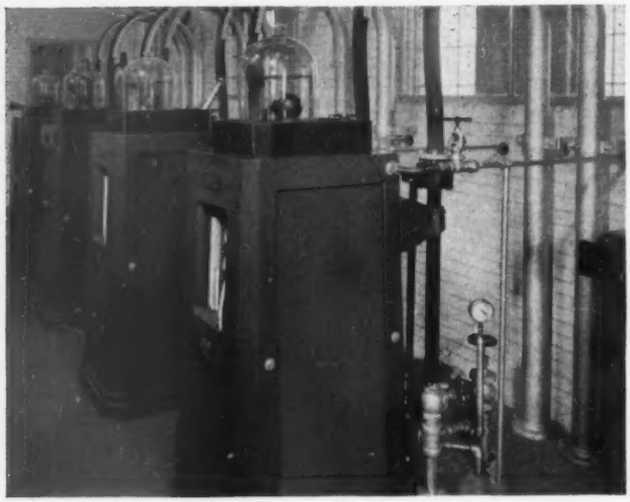


At Cermak Pumping Station, Chicago, Ill., Four W&T Master Visible Vacuum Chlorinators provide a total chlorine capacity of 3000 lbs. per day.

CHLORINATION

Chlorination is the accepted standard of sterilization in water works practice. Costing only a few cents per million gallons of water treated, easily applied, simply controlled and positive in bactericidal action, it has contributed more than any other one measure in reducing America's typhoid death rate from 30 per 100,000 to less than 3. Whether the source of supply is polluted surface water or clear, sparkling well or spring, its purity should be insured by the certain protection chlorination provides. Over 23,000 units of Wallace & Tiernan equipment in all parts of the world attest the universal accord with which chlorination and W&T Chlorinators are accepted.

TASTE AND ODOR CONTROL WITH BREAK-POINT CHLORINATION

Chlorination to the BREAK-POINT is a convenient way of describing the phenomenon produced in many waters when very much larger rates of chlorine are applied than has heretofore been customary standard practice. Hundreds of tests have shown that with most waters there is a rate of chlorine application that will be sufficient to break down taste producing organic matter and at the same time leave residual chlorine at a minimum.

The results which have been secured by BREAK-POINT Chlorination in a large number of instances have been so spectacular as to be almost unbelievable. Tastes and odors so severe as to bring an avalanche of complaints from consumers have been eliminated.

AMMONIATION

The ammonia-chlorine process has proved itself to be a valuable aid in the solution of many water works operating problems. Chloramine—formed by the combination of chlorine and ammonia—while somewhat slower in bactericidal action than chlorine, offers many distinct advantages particularly on small gravity water supplies of widely fluctuating flows.

Chloramine eliminates chlorophenol tastes and because of its more persistent residual, prevents aftergrowths in the distribution system . . . offers more effective algae control and prevents subsequent pollution by carrying sterilizing action all the way to the consumer's tap.

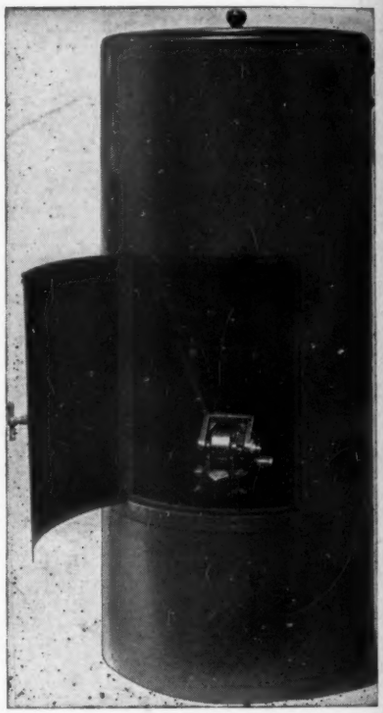
APPLICATION OF DRY CHEMICALS

The development of dry chemical application has been of great value in both sanitary and industrial fields. Difficulties from leaking tanks, corroded constant level boxes, clogged orifices, broken valves, and all the untidiness and disagreeable features incident to solution feed systems are eliminated. Of particular advantage in filter plants for applying alum, lime, soda ash or carbon, dry chemical application effects large savings in labor and materials.

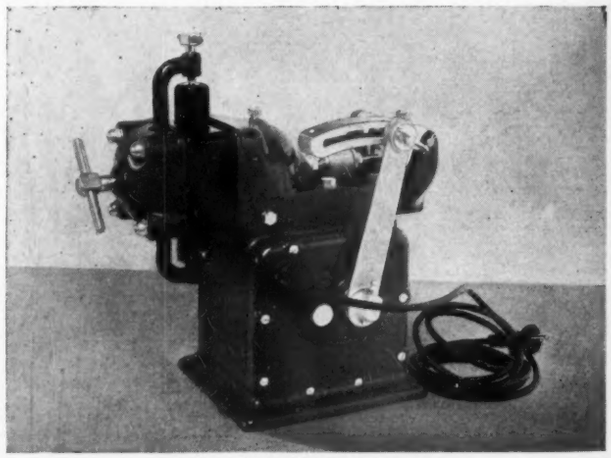
CHEMICAL SOLUTION FEEDER

Some chemicals such as hypochlorites are readily available in solution form and present problems in dry feed which make it desirable to handle them in solution form.

The W&T Chemical Solution Feeder is designed to feed chemical solutions such as sterilizing agents, coagulants or corrosion inhibitors with accuracy and dependability.



Type MOF Dry Chemical Feeder for accurate control of Alum, Lime or Activated Carbon.



W&T Chemical Solution Feeder

W&T EQUIPMENT

Complete in both arrangement and capacity, the W&T line of Chlorinators, Ammoniators, Dry Chemical Feeders and chemical solution feeders is designed to meet every water works requirement. Long life, low maintenance and utmost accuracy and dependability characterize each installation, reinforced by the services of a nationwide organization operating from 32 Sales and Service Headquarters. The recommendation of W&T field representatives involves no obligation. Feel free to call on them.

Current literature on the many phases of chlorination, ammoniation and chemical feed is available on request.

A SPECIAL INDEX FOR SEWERAGE TOPICS NOW APPEARS WITH THE GENERAL INDEX AT THE BEGINNING OF THIS SECTION

PART 7

SEWAGE TREATMENT

WATER WORKS & SEWERAGE

REFERENCE & DATA SECTION

1941

Readers will note that this section devoted to sewerage and sewage treatment has been rather markedly enlarged this year.

% PROPORTIONEERS, Inc. %

"CHEMICAL-FEEDER HEADQUARTERS"

9 NO. CODDING STREET, PROVIDENCE, R. I.

Representatives in Principal Cities

Raw Sewage Conditioning using Ferric Chloride and Lime can be controlled in proportion to variable flows thru the Venturi Tube, or over a Weir, measuring the influent. Ferr-O-Feeder can handle concentrated 43% ferric chloride or any dilutions; also ferrous salts and practically any other chemicals needed in sewage plants.

Fig. 1—Standard Ferr-O-Feeder

Sludge Dewatering—Sludge dewatering plants using vacuum filters must automatically control coagulant administered. A Ferr-O-Feeder, used as an adjunct to the vacuum filter, measures ferric chloride and delivers it under pressure to proper point of application in mixing chamber. Ferr-O-Feeder not only accurately measures corrosive liquids but, due to positive displacement method, can deliver the chemical remotely to upper floors of the plant—wherever the filters and dewatering equipment may be located. This eliminates the need of additional rubber lined pumps for lifting or moving ferric chloride from storage to point of use. Ferric feeder is controlled by cross connection to sewage pumps; to drive motors of vacuum filters; or by belt or chain and sprocket connection to bucket elevators (see Fig. 3).

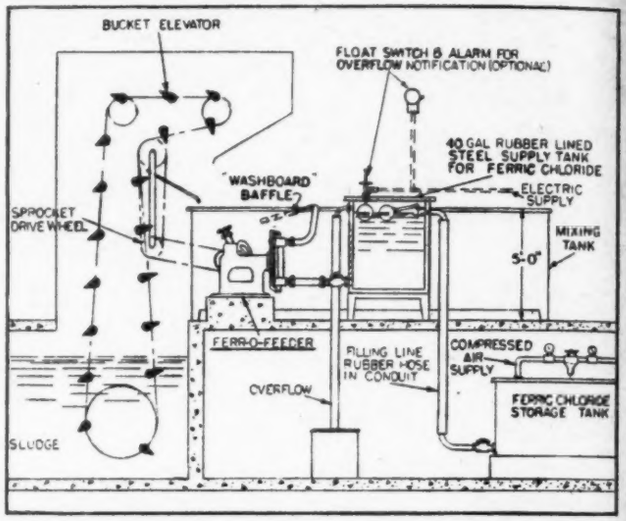


Fig. 3—Installation Diagram Ferric Chloride Feeder Controlled by Bucket Elevator

Chem-O-Cabinet is a single unit for permanent installation or for portable emergency operation, a unit that will feed any chemical used in sewage treatment. It is a complete installation, all ready for the operator to set in place, and tap into the line. As shown in Fig. 4, it is made up of the following: 85 lb. per square inch pressure proportioning pump (also capable of feeding into negative pressure zones), mounted on steel cabinet with all accessories including: parts to easily interchange for feeding various chemicals, folding rubber bag, Orthotolidine test kit, and spare parts for year's service.

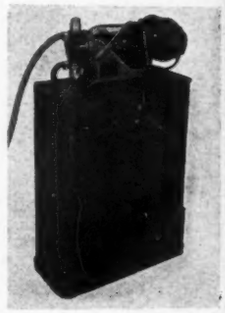


Fig. 4.—Chem-O-Cabinet

Chlor-O-Feeders for Odor Abatement—Hypo-Chlorite sterilization of sewage effluent (Fig. 5) is widely practiced in Airports, Army Camps and other small sewage plants for odor abatement. Depending upon local conditions, Chlor-O-Feeder chlorinates constantly; is manually started and stopped as required; is connected to automatically start and stop with the sewage pumps; or is operated, automatically controlled, from sewage syphon.

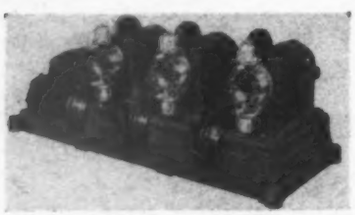


Fig. 2—Triplex Multi-Control Feeder

Multi-Control Feeders—Multiple feeding of several chemicals has been standardized so that 2, 3, 4, or more synchronized feeders, "ganged" on one drive mechanism (Fig. 2), can be ordered from stock.

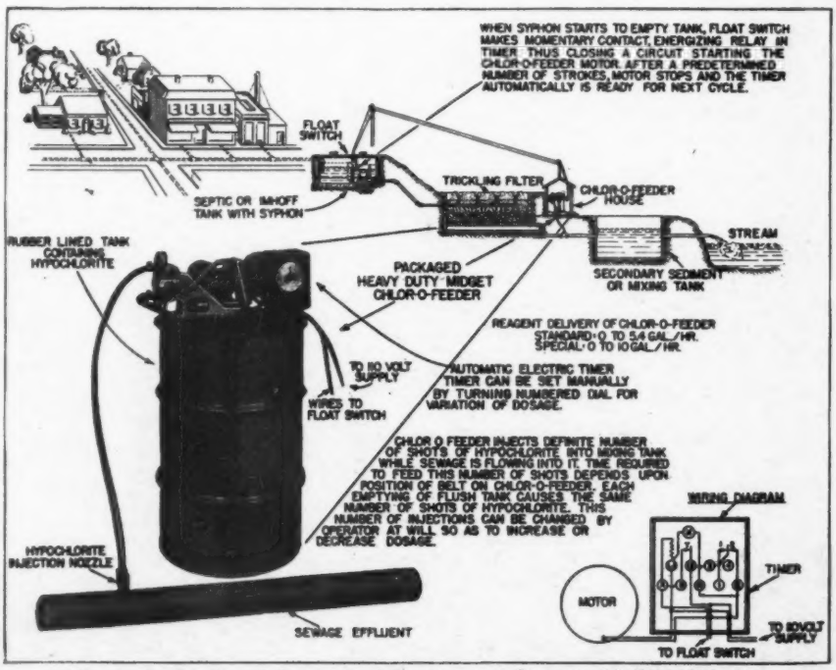

WHEN SYPHON STARTS TO EMPTY TANK, FLOAT SWITCH MAKES MOMENTARY CONTACT, ENERGIZING RELAY IN TIMER THUS CLOSING A CIRCUIT STARTING THE CHLOR-O-FEEDER MOTOR. AFTER A PREDETERMINED NUMBER OF STROKES, MOTOR STOPS AND THE TIMER AUTOMATICALLY IS READY FOR NEXT CYCLE.
FLOAT SWITCH
TRICKLING FILTER
CHLOR-O-FEEDER HOUSE
SEPTIC OR IMHOFF TANK WITH SYPHON
STREAM
RUBBER LINED TANK CONTAINING HYPOCHLORITE
PACKAGED HEAVY DUTY MIDGET CHLOR-O-FEEDER
SECONDARY SEDIMENT OR MIXING TANK
REAGENT DELIVERY OF CHLOR-O-FEEDER STANDARD: 0 TO 5.4 GAL./HR. SPECIAL: 0 TO 10 GAL./HR.
TO 110 VOLT SUPPLY
AUTOMATIC ELECTRIC TIMER TIMER CAN BE SET MANUALLY BY TURNING NUMBERED DIAL FOR VARIATION OF DOSAGE.
WIRES TO FLOAT SWITCH
CHLOR O FEEDER INJECTS DEFINITE NUMBER OF SHOTS OF HYPOCHLORITE INTO MIXING TANK WHILE SEWAGE IS FLOWING INTO IT. TIME REQUIRED TO FEED THIS NUMBER OF SHOTS DEPENDS UPON POSITION OF BELT ON CHLOR-O-FEEDER. EACH EMPTYING OF FLUSH TANK CAUSES THE SAME NUMBER OF SHOTS OF HYPOCHLORITE. THIS NUMBER OF INJECTIONS CAN BE CHANGED BY OPERATOR AT WILL SO AS TO INCREASE OR DECREASE DOSAGE.
WIRING DIAGRAM
HYPOCHLORITE INJECTION NOZZLE
TIMER
MOTOR
SEWAGE EFFLUENT
TO 60 VOLT SUPPLY
TO FLOAT SWITCH

Fig. 5—Automatic and Proportional Treatment of Sewage with Hypo-Chlorite

PART II. SEWERAGE

Whereas, this section is devoted almost exclusively to Sewerage, it was not possible to segregate material which pertains to Water Works as well as Sewerage, except at the expense of duplication. The Water Works Section contains considerable material of direct bearing on Sewerage.

SEWERAGE FINANCING

Modern Methods and Experience

By W. F. TEMPEST, Engineer*

Municipal Bureau, Portland Cement Association, Chicago

PRACTICAL methods of financing sewerage improvements are urgently needed and eagerly sought. From experience and study of modern methods of sewerage financing, the merits of sewer rentals and sewer revenue bonds are being brought into sharp focus. There is immediate need for more factual data from municipalities which have had actual experience in formulating rate schedules for service charges and in the application of this method to financing with sewer revenue bonds. Experiences as outlined by Robert A. Allton of Columbus, in earlier issues of WATER WORKS & SEWERAGE, and by others, are of timely interest and should be of value to municipalities seeking the most practicable means of financing the needed facilities.

Enabling Acts

Although enabling acts for financing with sewer rentals and revenue bonds have now been passed in thirty-four states, the emergency nature of some of the acts makes necessary some clarifying amendments to broaden the scope of the borrowing power of municipalities. In a few cases the acts are not permanent but in those states consideration is being given to revision and passage of legislation that will be permanent.

Full appreciation of the benefits of such legislation is not yet general and even in many states with adequate legislative provisions, municipalities have failed to take advantage of it.

Sewer Rental May Be Charged Without an Enabling Act

It is desirable to have a clear definition of the terms "Sewer Rentals" and "Revenue Bonds." Sewer rental is a service charge made for use ofthe sewerage system and the treatment works. In some cases it is applied only to the treatment works, but its application to the entire sewerage system is becoming more general. The charges are usually made monthly or quarterly and paid by the user, not necessarily the owner of the property served. The revenue from such service charges is used to pay for operation and debt service in whole or in part.

CITY OF EDWARDSVILLE, ILL.
SEWER SERVICE RENTAL

DOMESTIC RATES (NET PER MONTH)	
Service Connection Minimum	$ .75
Up to 12,000 Gallons	.75
12,000 to 22,000 Gallons	1.25
22,000 to 32,000 Gallons	1.50

COMMERCIAL RATES (NET PER MONTH)	
Service Connection Minimum	$1.50
Up to 15,000 Gallons	1.50
15,000 to 25,000 Gallons	1.75
25,000 to 35,000 Gallons	2.25
35,000 to 45,000 Gallons	3.25
45,000 to 100,000 Gallons	5.00

FLAT RATES (As Per City Ordinance No. 604)

Bills are payable to City of Edwardsville at City Hall. EDWARD H. POOS, City Clerk.

Note: If bill is not paid within 10 days after date below a 10 per cent penalty is added to net amount.

Date of this bill .....

Rental for this month .....

Amount forwarded .....

TOTAL AMOUNT .....

AMOUNT PAID .....

DATE OF THIS BILL .....

Note: When paying by mail please enclose this stub.

In Edwardsville, Illinois, this separate form of bill, printed on the back of a penny post card, is mailed to customers each month.

The sewer rental method may, in fact, be used to retire general tax obligation bonds, as described by Robert A. Allton in his article in this magazine discussing sewer rentals in Columbus, Ohio; or it may be used to retire other certificates of indebtedness. Its use is not confined to revenue bond financing and may be applied in states *without* enabling legislation for revenue bonds.

Revenue bonds are considered a form of municipal bond issued by a political subdivision for the purpose of constructing, acquiring or improving revenue producing works such as sewerage, sewage disposal and water works. Payment of such bonds depends entirely upon the revenue of the utility. The issuance of revenue bonds does not add to the bonded indebtedness of a municipality within the meaning of constitutional or statutory debt limitations. It is, therefore, possible for a municipality to finance improvements by this method when it would otherwise be impossible because of stringent limitations. However, as pointed out by prominent municipal bond houses, revenue bond financing should not be considered an easy entrance into debt for the improvident municipality. Although the full faith and credit of the political subdivision is not directly pledged as security for revenue bonds, the financial standing and debt history of the municipality will have an important bearing on the value and marketability of the bonds.

Referendum and Education

In many states it is possible to issue revenue bonds without a vote of the people. All that is necesary is a satisfactory bond ordinance passed by the council. Many have found it desirable, however, to ask for a referendum even though not legally required. When this is done it is important that the public be fully informed regarding the need for the improvement, its cost and the proposed service charge. Lack of an honest and intelligent publicity campaign may result in the defeat of a bond issue for an urgently needed improvement. An educational campaign is desirable regardless of whether a referendum is held or not. Publication of facts about the improvement and benefits to the municipality will react in many ways favorable to the city. General statements also will aid in giving the public, and especially investors, simple facts from which they gain some appreciation of the character of the municipality. Such facts will include growth of the community, industrial, business and residential, improvement programs, administration, debt control, tax rates, collections, particularly favorable experience in water and sewer bill collections.

Billing and Collection Experiences

Reports assembled recently from municipalities in 17 different states showed 92 cities charging sewer rentals and in only two or three were there any difficulties reported with collections. Even so, the average uncollected balance of those reporting delinquencies was not as much as 5 per cent. A few reported mild protests on the first bills but these soon disappeared. In one case delinquencies were high due to protests at not having a referendum, and in another case there was disagreement between owners and renters on who should pay.

The billing method most preferred seems to be the monthly basis, and 50 per cent of the cities for which information was

* The author is Secretary of the Committee on Joint Administration and Collection of Water and Sewer Charges of the Am. Water Wks. Ass'n.

Date.....193...

CITY OF MITCHELL
WATER BILL

DEPARTMENT OF WATERWORKS

Meter Reading at End of Period - - - - .....
Meter Reading at Beginning of Period - - .....
Gallons Water Consumed..... Amount $.....

No deductions made on account of leaks or water wasted.

Unpaid Previous Balance - $.....
Total Due Water Dept. - $.....

PLEASE NOTE
MINIMUM CHARGES
WATER—Per Mo. $1.00 (2500 Gals.)
SEWER—Per Mo.....
Bills are payable for each month's service during the first 10 days of the following month. A charge of $1 is made for reestablishing services disconnected for non-payment.

CITY OF MITCHELL
SEWER BILL

DEPARTMENT OF SANITATION

Total Gals. Water Used..... Amount $.....
Unpaid Previous Balance $.....
Total Amount Due for Sewer Service $.....
TOTAL AMOUNT DUE—WATER AND SEWER SERVICES $.....
PLEASE BRING THIS CARD WHEN MAKING PAYMENT

City of Mitchell

WATER BILL

This Month $.....
Arrears - $.....
Total Due
Water Dep. $.....

SEWER BILL

This Month $.....
Arrears - $.....
Total Due
Sewer Dep. $.....

Total Amount DUE $.....

Return This Stub when paid by check.

Mitchell, Indiana, sends out one billing card, but shows water and sewage charges separately.

tabulated send sewer rental bills out monthly, most of the others quarterly or semi-annually. Six cities in Pennsylvania and one in Virginia reported annual billing.

The Rate Basis

The rate basis for the service charge in most cases was on the metered water consumption. In general this is the simplest and most equitable. The rate schedule should in all cases bear a relation to the use of water, even though the charge is assessed as a flat rate. Also general benefits should be considered when the charge is made on the basis of the water meter readings. There is a direct benefit accruing to the property from sewerage improvements and it is recognized that the owner should pay a certain share of the cost of the improvement. This charge may be made against the owner when connection is made to the sewer. Determining a rate schedule will also involve consideration of the character of the different areas served, that is whether domestic, business or industrial, and the quality of the sewage. The proper schedule of charges will necessarily have to be worked out for each specific case, and the municipal officials should give every possible assistance to the engineer in establishing a fair rate basis which will subsequently be incorporated in the rate ordinance.

Legal Advice Important

The actual financing of the project should be discussed with a well recognized firm of bond attorneys and with bond houses specializing in municipal securities. Many bond houses now recognize the special merits of revenue issues and are steadily building up a market for sewer revenue bonds. With continued favorable experience with this type of bond its use should spread to a large number of municipalities in states having satisfactory legislation. So far the sewer revenue method of financing has been most popular in the mid-western states. It has been applied to a limited extent in some eastern states and a number of cities in the western and Pacific Coast states have shown a live interest and a desire to finance sewerage improvements with revenue bonds. No actual experience has yet been reported, however, from the far West.

Special Authorities Not Usually Necessary

In most cases where the sewer rental and revenue bond methods of financing have been used it has not been necessary to create new units of government. There is no basis for a fear that revenue financing will result in new overlapping units of government. It does, however, bring about a closer cooperation in the administration of the waterworks and sewerage divisions of the city. In this way it is possible to achieve economy, especially in billing and collections.

Where special "authorities" have been formed, peculiar conditions and circumstances were such as to make this form of administration the most advantageous. The unique quality and the high order of the executive work of these authorities where they were definitely needed has won the respect of those whom they serve and those with whom they deal. The formation of a separate corporation or "authority" is a device to be employed only under special conditions. Its general adoption is not necessary for a wide and successful use of the sewer rental method, or for the increased use of revenue bond financing.

It is to the best interests of all municipalities to give serious consideration to these sound methods of modern sewerage financing. This relatively new method of financing will be especially useful when federal grants for public works have been materially reduced. It will enable municipalities to obtain needed facilities otherwise impossible without disturbing their existing fiscal program. Therefore the "Sewer Rental" method of financing sewage disposal deserves the careful consideration and study by all concerned. With the trend in the direction of consolidation of water works and sewerage departments of municipalities, water works managers should be especially interested in the modern and scientific method of financing through sewer rental collections.

Exhibits and Illustrations

Now will be presented some illustrations of how the method is employed and typical exhibits of billing forms.

The following significant recommendations of the Investment Bankers' Association concerning Special Revenue Bonds are taken from an extract which appeared in the Commercial & Financial Chronicle:

"Special Revenue Bonds:

"Reference is made to a resolution adopted by the Board of Governors on May 11, 1937, that part of which outlining specifications is as follows:

"That advertisements or circulars describing revenue bonds shall clearly indicate the nature of the obligation.

"That the customary form of the ordinary municipal circular and advertisement be varied to prevent confusion in the mind of the casual or careless reader.

"That the type of obligation be described clearly in the caption and with prominence consistent with that accorded to the name of the municipality.

APRIL BILL
Payable on or Before April 30, 1938

Failure to Receive Bill Does Not Excuse Consumer to Net Amount
WHEN PAYING AT OFFICE, Please Bring Entire Bill.
OFFICE HOURS—8:00 a. m. to 5:00 p. m. On the 5th of the month 8:00 a. m. to 8:00 p. m.
CLOSED SATURDAY AFTERNOON—if last day of month falls on Saturday, Sunday or a Holiday. Net Bill will be collected on the following business day.

CITY OF GRAND HAVEN
SEWAGE DISPOSAL DEPT.

Service Charge	Arrears

10 Per Cent Penalty Added after April 30, 1938

PAYABLE ON OR BEFORE APRIL 30, 1938
Sewage Disposal Dept.
WHEN PAYING BY MAIL ATTACH THIS STUB TO YOUR CHECK OR MONEY ORDER

Service Charge	Arrears

A separate bill is used by the Sewage Disposal Department of Grand Haven, Michigan. The rates, based on water meter readings, for quantity per quarter at monthly charge are as follows: Up to 5,000 *gals.*, $0.50; 6,000 *to* 10,000 *gals.*, $0.75; 11,000 *to* 15,000 *gals.*, $1.00; 16,000 *to* 20,000 *gals.*, $1.25; 21,000 *to* 25,000 *gals.*, $1.50; 26,000 *to* 50,000 *gals.*, $2.50; 51,000 *to* 100,000 *gals.*, $4.00; 101,000 *to* 200,000 *gals.*, $6.00; 201,000 *to* 500,000 *gals.*, $10.00; 501,000 *to* 1,000,000 *gals.*, $15,00; *over* 1,000,000 *gals.*, $25.00

"That priority of obligation, if any, be stated specifically.

"That the statement of assessed valuation, total debt, etc., if included, be given a secondary rather than a primary position.

"That in connection with such statement of assessed valuation, etc., a statement shall be made, and prominently displayed, to the effect that the assessed valuation reported is not subject to taxation for the payment of principal or interest of the bonds."

Bill for MUNICIPAL UTILITY SERVICE (Service of the Combined Waterworks and Sewerage System)
CITY OF ELMHURST, 132 Addison Ave., ELMHURST, ILLINOIS Tel. Elmhurst 1800
OFFICE HOURS: 8 A. M. TO 5 P. M.—WEDNESDAYS 8 A. M. TO 12 NOON

READING DATE FROM	READING DATE TO	METER READINGS PRESENT	METER READINGS PREVIOUS	WATER CUBIC FEET	QUANTITY CHARGE	GROSS BILL	Discount For Prompt Payment Only	PREVIOUS BILL UNPAID	TOTAL AMOUNT DUE
		SERVICE CHARGE (SEWAGE DISPOSAL) →							

QUANTITY CHARGE (Measured by Water delivered and based on one month's usage.)
Any portion of the
FIRST 4,000 Cubic Feet @ $2.25 per 1000 Cu. Ft.
NEXT 16,000 " @ 1.87½ "
" 60,000 " @ 1.50 "
All Additional " @ 1.12½ "
Minimum Quantity Charge .75 per Month

SERVICE CHARGE per month.
Single Family Residence $0.80
Duplex " " 1.60
Apartment and Office Bldgs. and similar class named in Ordinance, 40% of quantity charge.
For other classifications see Ordinance.

SAVE YOUR DISCOUNT—5% IF BILL IS PAID WITHIN 10 DAYS OF DATE. MAKE CHECKS PAYABLE TO CITY OF ELMHURST.

BILLS PAYABLE AT
CITY OFFICE, 132 ADDISON AVE YORK STATE BANK, 529 SO. YORK ST. HIERONYMUS DRUG STORE, 500 SPRING RD. OTTO'S GROCERY & MARKET, 675 W. ST. CHARLES RD.

One Form of Combined Bill for Water and Sewerage Utility Service Rendered Monthly
In this case the "Service Charge" for sewage disposal is on a simple fixed monthly basis, and is very nearly the same as the minimum "Quantity Charge" for water used.

[We recommend to the reader the 120-page brochure "Sewer Rentals," recently published by the American Public Works Association, 1113 East 60th St., Chicago.—Cost to non-members, $1.50.—Ed.]

SLIDE RULE FOR SEWAGE PLANT OPERATORS

Contributed by A. A. Hirsch, Instructor, State Dept. of Education, Baton Rouge, La.

The triple-purpose slide rule shown here was devised for operators of sewage disposal plants—especially the smaller plants. In one setting it solves the calculation of % Solids Removed by sedimentation tanks, and also gives chlorine dosage from the daily pumpage and amount fed. It will be noted that the upper two logarithmic scales serve dual functions.

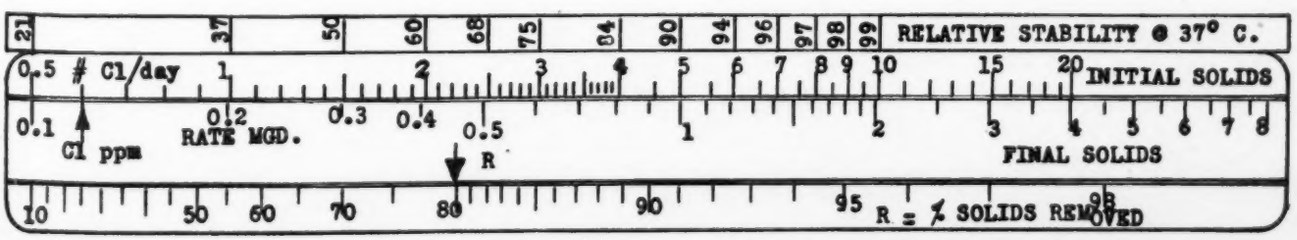
A superimposed scale gives Relative Stability at 37° C. corresponding to days storage as marked off on the scale labeled "Initial Solids." This strip (at top) is intended to be cut off and glued inside the slideway of the rule.

Calculation of % Solids Removed is as follows: Set the "Final Solids" figure (ml./L) on the slide exactly opposite the "Initial Solids" figure on the top stock; arrow (R) will then indicate % "Solids Removed" on the bottom scale.

To calculate chlorine dosage: Set the pumpage (M.G.D.) on the slide opposite the amount of chlorine red (lbs./24 hr.) on the top scale; the arrow marked (Cl) points to the chlorine dosage (p.p.m.) on the top scale.

This rule can also be used very conveniently for figuring per cent removal of other quantities than solids, for instance B.O.D. removal, by employing the Solids scales, with an appropriate multiplier in order to locate the result on the bottom scale. Thus for B.O.D. improvement caculations the Initial B.O.D. divided by 100 is located on the top scale; under this point the final B.O.D., also divided by 100, is set on the slide; the arrow R then gives per cent B.O.D. removal directly on the bottom scale.

By virtue of the simple logarithmic rulings on the Initial Solids and Final Solids scales, these two scales may also be used for ordinary multiplication and division. In this way activated sludge plants will find these scales handy in figuring the Sludge Index.



SEWER MAINTENANCE

Some Practices Developed from Experience

By C. GEORGE ANDERSEN, Superintendent
Dept. of Sewers and Sewage Disposal
Rockville Centre, Long Island

In the sewerage problems of today the treatment plant and types and design of sewers seem to take the lead. Now, when one considers the investment in sewer lines as the primary structure, providing an indispensable service in the removal and disposal of sewage, we are in general too negligent in the matter of maintenance and operation of sewers for the best interests of the public and efficient functioning of the treatment plant.

At Rockville Centre the writer, like many other men in charge of sewerage systems and sewage treatment, had his problems. The first was the effective and economical treatment of liquid and solids at the treatment works. Then, after catching up on this important phase of the cycle, in looking around it seemed important to face squarely the other sewerage investment amounting to four times as much,—namely, the sewers. In Rockville Centre we have not so many miles of sewers, nor very large ones, but those we have are as important to proper functioning of the entire system as though they were in a metropolis. The sizes range from 8 to 30 inches, and these sewers clog with roots, sand and many other materials.

Sewer Cleaning

Sewer cleaning being one of our problems, after our sewer lines are laid it becomes a necessity to maintain them in good working condition, and we might just as well lay out a program of routine cleaning and maintenance, rather than wait until trouble overtakes us. Continuing and repeated emergency calls, growing out of sewer stoppages, is very costly. In addition to extra expense there results many disgruntled taxpayers, inconvenienced by stoppages and put to added expense, due to their sewer lateral being plugged because of some backage in the main in the street.

Some Notes on Equipment and Its Effectiveness

For sewer cleaning and removal of roots, there are many types of equipment now available. Flexible steel sewer rods are a recent innovation in such equipment. These rods have an advantage in that the necessity for going down in manholes is eliminated. The rods are made up in three foot lengths, which coupled together make one complete flexible rod that is usually coiled between uses. Wood rods of five foot lengths (coupled together as they are being pushed into the sewer line) also continue in use to some extent. The wood rods, being more rigid than the steel rods, follow a straight line more successfully, but cannot be turned and forced to the extent that the new flexible steel rods can.

The "Turbine" type of sewer cleaning instrument is probably the most positive of all types made today. This device (adjustable to any diameter sewer) is a water powered rotating cutter. In employing the "Turbine", it is necessary to have two winches and cable to draw it through and back between manholes in the line, while the high speed rotating knife blades do a clean job of root cutting and scaping.

Rods of any kind, which can be used efficiently in making time and mileage when going over an entire sewer system as laid out in a program, are good up to a certain point such as the removal of small deposits and light root growths. On the tougher jobs, such as spots where knob roots have formed (see cut), a more positive applied type of equipment is required. In such cases it becomes necessary to use the "Turbine" cutter, or some similar tool, that will slowly but surely remove the obstruction if it is such as can be cut by steel.

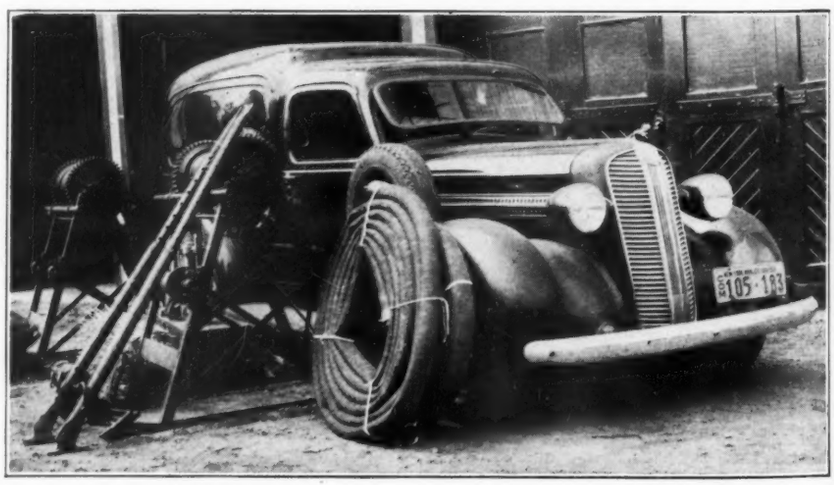
I stress this point, because on one occasion a severe stoppage occurred in an eight inch line. Our Flexible sewer rods were first used, but could only give relief to the extent of four inches. That is, the four inch auger-head was the largest tool that could be forced through. The supposition in this case was that the trouble was caused by a broken spur, being replaced by a makeshift stack which extended into the sewer line. Many other suppositions also were expressed, but there is only one thing to do in a case like this (and such is good for experience)—dig it up. This was done and the trouble was, in fact, at a spur. The spur was not at fault, however, but through the joint preceding it a large root had entered. The question was, how to remove it. A hole was cut in the eight inch tile sewer line so that action of the available cutting tools could be observed as it was applied to the root. The root had formed a five finger knob on the top inside of the pipe (see cut). When the Flexible sewer rod with the auger used in eight inch line was applied to the root the tool just jumped back and had no effect. This satisfied me as to the necessity of having a positive applied sewer cleaning cutter, especially for clearing out those very deceiving *top* roots which cannot be removed by auger and do not stop sewage flow until they are definitely a menace in the sewer.

Sand and gravel which have built up around paper, roots and other matter in a sewer, are also a headache. We find that one cannot have *too much* equipment. And, we have also learned that in sewer maintenance different makes of equipment can be used in combination or in sequence to produce very efficient work. Take the case of sand; Flexible steel rods can be used to get an opening through the sand. This constitutes the first important step. Then a cable may be drawn through so as to draw a bullet or tool for loosening and liquifying sand stoppage. Thereafter, the Turbine flusher or cleaning buckets, whichever proves the more efficient, may be used.

Mapping and Program Setting

In setting up our maintenance program, the village map was taken and divided into sections, each section being given a number. In connection with the map, a section book, card index and a daily log book was also established. The section-book is made up of all the sewer sections, showing the sewer lines flush manholes, distances between manholes, etc. Each page (map) covers a separate section (see cut) and the crew operating makes constant use of detail maps in the field. The card index is set up

(*Continued on page* 135)



Our Maintenance Truck and Equipment
A 1½-ton unit, which seems a little light. A 2½-ton unit we believe preferable.

SINCE 1901

W. H. STEWART

Sewer Cleaning Equipment

P. O. Box 581
JACKSONVILLE, FLA.

P. O. Box 767
SYRACUSE, N. Y.

STEWART WOOD AND STEEL SEWER RODS

JUMBO No. 10 HEAVY DUTY WOOD RODS

Lengths:
2½, 3, 3½, and 4 ft.

Woodstock:
Selected hickory 1⅜"x1½" octagon

Couplings:
Strong, Malleable Iron

Triple Lock heavy duty sewer rod. Impossible to buckle or uncouple in the sewer. The tongue and groove eliminate wear on the hook, increasing the length of service.

Rods may be coupled or uncoupled on street surface. Will stand forcing with jack or windlass.

Free Trial—The Rods must Pay for themselves.

SECTIONAL STEEL RODS

Double Lock highly tempered spring steel rods.

⅜" Jumbo for heavy duty and 5/16" for light work.

3 ft. or 5 ft. lengths.

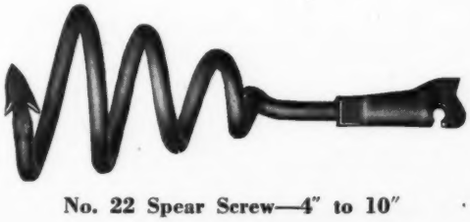
Rods connect by sliding in from the side. When the coupling is closed, a double lock prevents opening while in use.

Can be operated from street level.

HAND TOOLS

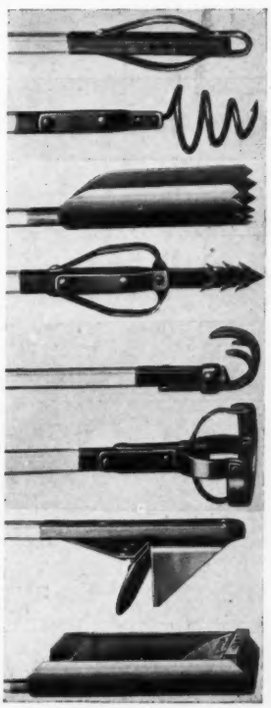
No. 11 Screw—4" to 10"

No. 12 Open Screw—0" to 00"



No. 22 Spear Screw—4" to 10"

1. **Leader—Jumbo Leader**
2. **Screw**
3. **Gauge**
4. **Spear**
5. **Claw**
6. **Plunger**
7. **Hinge Hoe Scraper —4" to 12"**
8. **Scoop—4" to 12"**

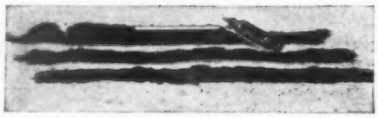


Guard Cage Collapsible Bucket 4" to 36"

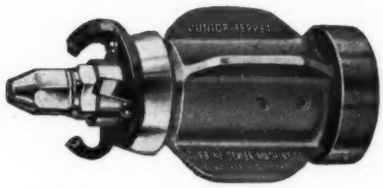
TURBINE SEWER MACHINE CO.

MILWAUKEE • WISCONSIN

EASTERN DISTRIBUTOR, TURBINE SEWER MACHINES SALES CO.
276 Lafayette St., New York City



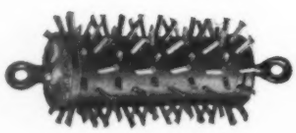
Roots Removed by Adj. Water Turbine



Self-Propelling Ferret Turbine

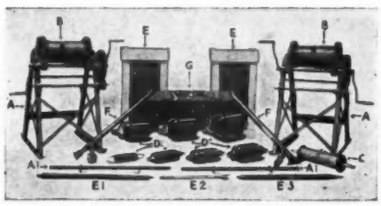
Go-Getter Self-Propelling Nozzle Without Knives

Go-Getter Nozzle With Knives

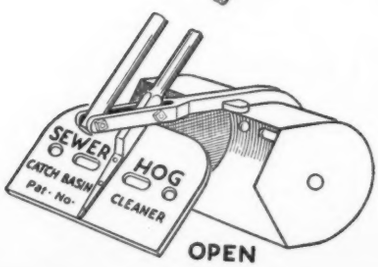


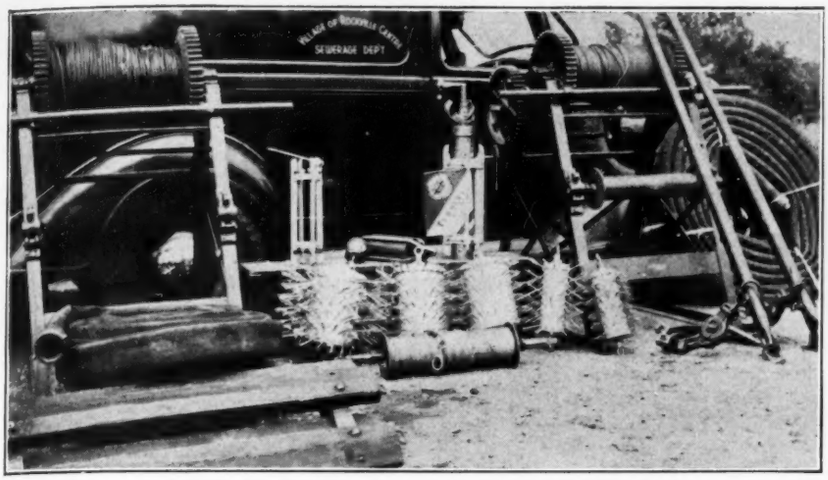
Improved Turco Hercules Sewer Brushes

Turbine Sewer Drag Outfit Type D



Turbine Flushing Bag





Some of the Equipment

Hose and guards in left foreground; a pair of cable winches, against one which leans cable braces with pulleys inserted in manholes to guide cables. In center, a spool of light threading cable and a set of effective metal scouring brushes (8 to 18 in) supplied by the Turbine Company of Milwaukee. Rear center, on chest containing cutting tools and sleds (6 to 20 in.) for Turbine Cutting heads, is a drag and Turbine Cutter complete for 8 inch jobs.

for each section and any conditions found worth remembering for the future is recorded on such cards. The log book maintained to show a complete record of all work done in connection with maintenance and cleaning, carries daily reports showing the number and location of the work section, the type of equipment found needed, number of feet of sewer cleaned, remarks on conditions, number of laborers employed and cost of the job for the day. A specimen page from the current log-book is here reproduced to better picture the type of entries made.

The plan of maintenance is so arranged that at least 78 miles of sewer will be checked once every three years or 26 miles yearly. The actual working time is 5 days per week during the spring and summer months only, involving in all about 150 days per year of maintenance work. The program is planned and timed to run from March 15 to July 1st, the work being resumed in September and terminated on November 15th. The reason for such a schedule is that it eliminates this type of work in the hot weather and also in the cold winter season, the two most disagreeable times to do this work in an efficient manner at least cost.

In the program the business area is done during the month of June, work commencing at 4 A. M. and stopping at noon. At this time of the day there is the minimum of traffic of any kind to hinder the work, therefore all work that is interfered with by traffic can be completed by the time traffic does start to move The three man operating crew consists of a leader, who must be a reliable, industrious individual, and two day laborers. A sewer inspector (or the superintendent) orders sections of work to be done, and likewise supervises the work and sees that adequate records are kept.

In connection with organization, consideration must be given to equipment mentioned and a transport for such. The truck does not have to be an unsightly thing. We use a 1½-ton black panel job, but find that a 2½-ton unit is preferable, as more space is available for the equipment, which consists of 1000 feet of hose, manhole and hose guards, Flexible rods and cutting tools, water powered Turbine, cutter, shovels, picks, lantern, flags, tools and emergency first aid.

The operation of the maintenance crew is to put through the sewers a tool that will either indicate a clean sewer, or remove stoppage, or determine the necessity for a more detailed job such as "turbining." In their travels they repair masonry in manholes, pack loose manhole lids that disturb residents because of banging under traffic.

In stopping rattling manhole lids many things were used which were unsightly on the streets. A gum was then used and served the purpose for a time. The most satisfactory thing to date has been a tape packing called "Tapax." It is laid around the full circumference of the manhole lid seat, after thoroughly scraping and brushing it clean.

In the larger sewers (15 inch and above) we find that the large wire brushes, that are part of our "Turbine" line of equipment, can be used more efficiently for cleaning and indicating trouble than can the Flexible steel sewer rods.

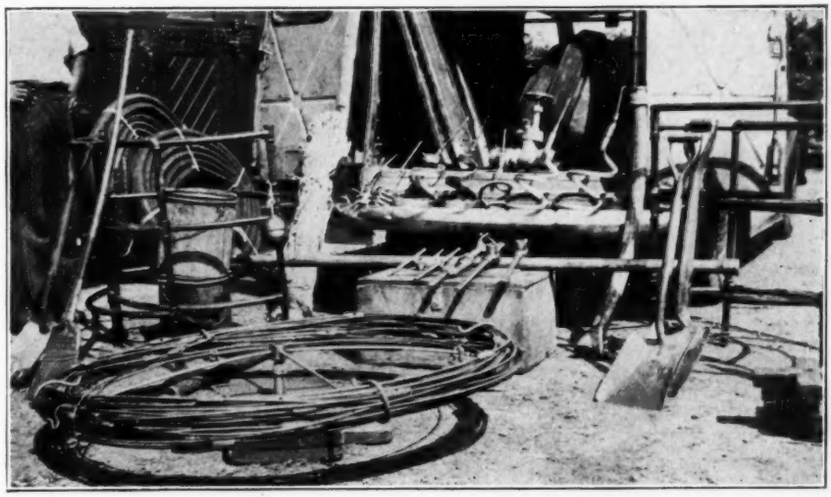
The mere looking down at the flowing sewage, after flushing, does not indicate a clean free-flowing sewer. This much the experience related previously herein has taught us.

Flushing

The basic requirements for effective flushing of sewers are splendidly presnted by J. D. Watson in WATER WORKS AND SEWERAGE for August, 1937. [The same article being reprinted in the Reference and Data Section for 1939.—ED.]

Sewers today are flushed both manually and automatically. The former method is done by using a hose or drawing from pond into the end manhole of a section of sewer line, known as a flush manhole. Also there is the automatic flush equipment frequently installed at the end of a line. The equipment includes a siphon arrangement built into the manhole and discharging into the sewer. The flush tank is continuously refilled by a constant regulated flow of water into it, the rate being controlled by a special faucet. In operation, the flush tank is filled to a certain depth by the water from the faucet. When the head of water is sufficient to cause the siphon to start operation, the siphon empties the tank rapidly and thus flushes the sewer. The idea in all cases of flushing, be it drawn from a pond, by hose, or automatic flush tank, is to cause the flowing off of sewage solids depositing in a flat grade or "lazy" sewer. The hose flushing is the most practical and effective method, as it can be applied anywhere along the line.

The automatic flush, which is still being used, has to be main-



Rear of Truck—More Equipment

Flexible sewer rods connected and coiled on revolving wheel stand. Rear of truck, replacement rods and various types and sizes of augers and screw heads (4 to 10 in.) for Flexible rod work; stop valve for controlling pressure from hydrants used in flushing and Turbine operations; Flexible rod man-hole guides, wrenches and ratchets; man-hole guards flag-stands, etc.

tained. The strainer and orifice through which the water flows to the tank has to be kept clear. Varying pressures in the water main has a tendency to loosen iron deposits which choke the strainer or orifice; also water that has been treated with lime and chlorine causes clogging and trouble with such equipment. There is also the cross connection hazard with this type of equipment which is now being eliminated as much as possible.

As mentioned before, a flow of water will not indicate a clean sewer. Unless properly applied water flow alone will not clean a sewer from a practical man's point of view, other than to flush through material that has been scraped and cut loose or those deposits that are rather easily moved. To clean a sewer effectively involves the removal of films that are building up to a thickness. To accomplish this, the positive scouring type of jetting nozzles must be run through the entire sewer. The flow from a fire plug may seem terrific on entering the line, but very soon levels out to nothing more than a fast flowing stream. As to how much it removes from the walls of the pipes is speculative.

Roots and Service Connections

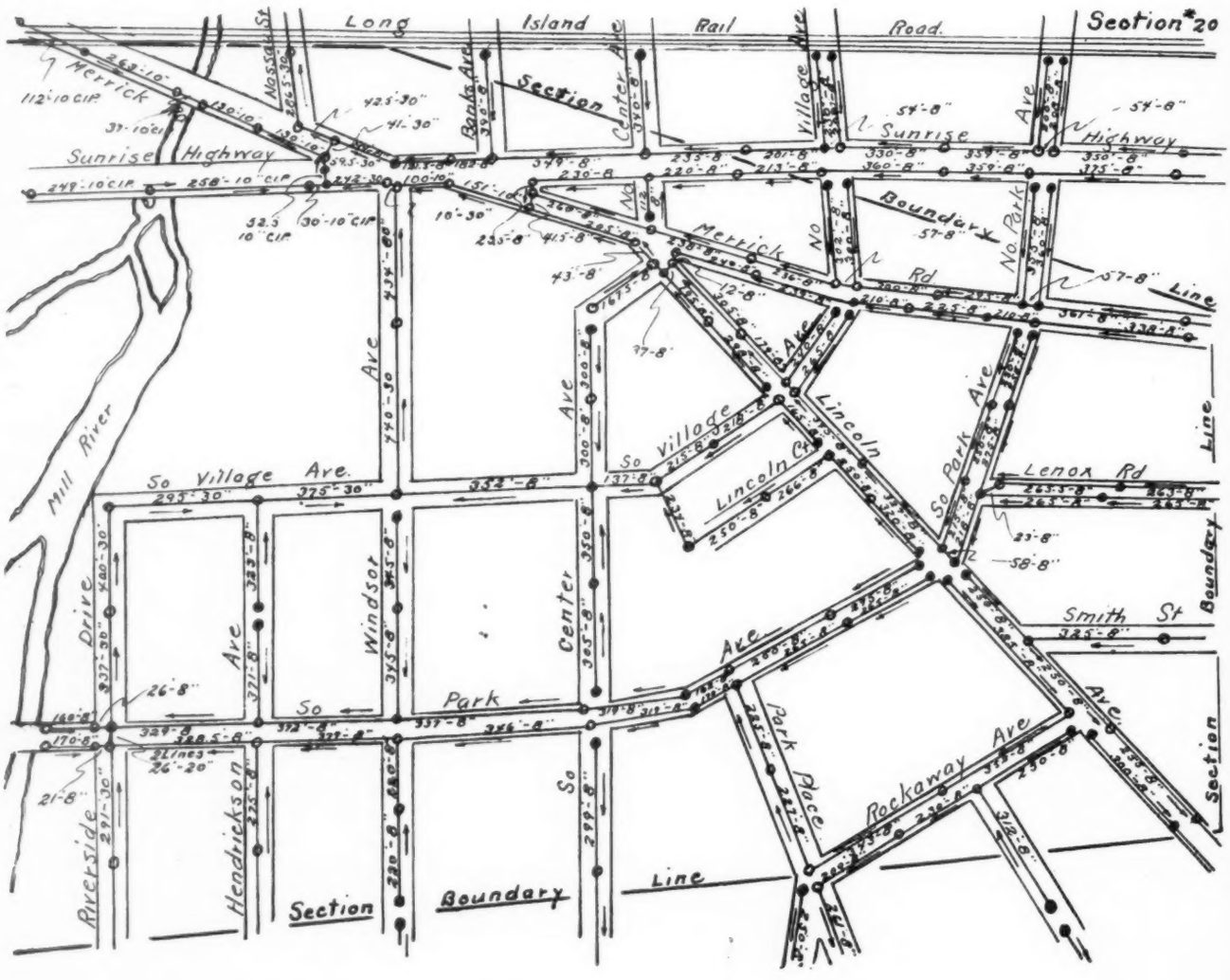
Roots are the big problem in sewer maintenance. We know where they come from—but how to control them? We can to some extent cut down the trouble in the following:

1. Stricter inspection of new lines being laid.
2. Material used for joints. This is no better than workmanship of labor performing the job.
3. Ordinance directed to elimination of the most prolific root growing trees such as poplars, swamp maples, weeping willows, etc.

It has been interesting to hear some of the reports as to how roots will be attracted to sewage, passing up water directly under them and reaching out for a crevice or bad joint in a sewer line. There are many contributing factors—the temperature of sewage, and its content of plant food being the more important.

Service connections into sewers should be inspected as to grade and workmanship of a joint. A poor grade and joint means future trouble for all concerned,—user and Sewer Department. It is so easy to take drain-layer's and plumbers' word for the work done, but once inspected and passed the installation becomes the responsibility of the department passing it. You may argue the point later and think that you have won out, but the taxpayer finally has his day, as we have witnessed so much of late.

The responsibility for maintenance of sewer connections results in a dispute many times. I contend and carry out the policy that where service charges are not made, a sewer lateral should be the sole headache of the one using it. The sewage and waste that is run out to the sewer comes from that property. Any trees in the vicinity are for his comfort, and for a department to take over responsibility from the curb to the main leaves us with the question, Where is the end? Most Sewer Departments have a limited personnel, and to be called out on each house stoppage occurring certainly makes a condition of despair many a time, because of the inability to catch up or demand more labor, which cannot



Detail Map—Section No. 20—Business District

Taken from our Section Map Book covering the 24 sections of the Rockville Center System—Practically indispensable in effective and economical maintenance work, recording, trouble finding, etc.

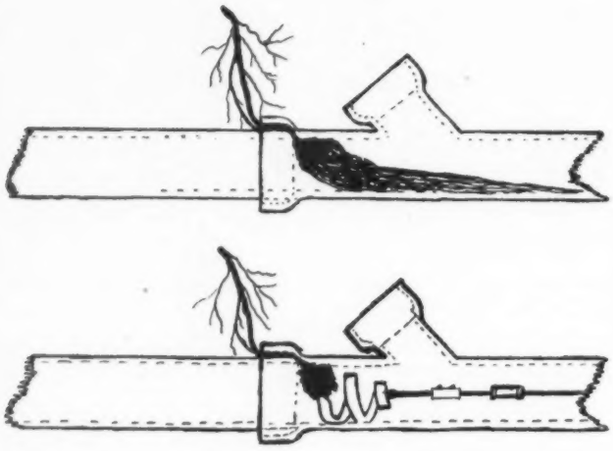
MAINTENANCE RECORD

RECORD OF ALL WORK DONE PERTAINING TO MAINTENANCE OF SEWERS

DATE	LOCATION OF WORK	SECTION	TYPE OF WORK DONE: FLEX. RODS	TURBINE CUTTER	FLUSHED	TOTAL FEET CLEANED	MISCELLANEOUS	REMARKS	NO. OF MEN	NO. OF HRS.	COST
4/4/39	So.Park Ave. bet.Lincoln Ave and Center Ave. S/S	20	X		X	489'		Found bad root condition	3	8	
4/5/39	S/S Lakeview west of Greenway St.	1	X		X	180'	On Complaint	Found break in line about 3' from 1st.			
4/11/39	S/S Park Ave bet.Center Ave and Riverside Drive	20	X		X	1053'		d.s.m.h.that filtered water & sand into sewer Bad root condition.	3 3	8 8	
4/11/39	N/S Park Ave.bet.Riverside Dr. and Center Ave.	20	X		X	1038'		Root condition - not bad	3	8	
4/12/39	N/S Park Ave.bet.Center Ave. and Lincoln Ave.	20	X		X	731'		Bad root condition	3	8	
4/12/39	E/S So.Village Ave.bet.Lincoln and Merrick Road	20	X		X	265'	On Complaint	Found roots in this line,no trees within 150' of stoppage	3	8	
4/13/39	N/S Park Ave.bet Center Ave. and Lincoln	20	X		X	275'		Bad root condition	3	8	
4/14/39	Center Ave.bet.Park Ave and Shellbank	20	X		X	869'		Bad root condition - broke several rods	3	8	
4/14/39	Windsor Ave.bet.Park Ave & flush manhole So. of Park	20	X		X	440'		Some roots - not bad enough to give trouble	3	8	
4/17/39	Windsor Ave. So. from flush manhole to Shellbank Place	19	X		X	440'		Light roots	3	8	
4/17/39	S/S Lakeview Ave West about 350' from Hempstead Ave	9	X		X	320'	Demonstration	New Sewer Cleaning tools used	3	8	
4/18/39	Hendrickson Ave. from Park Ave so. to Shellbank Place	20	X		X	980'		Bad root condition	3	8	
4/18/39	Hendrickson Ave from F.M.H. No. to So.Village Ave	20	X		X	323'		Very bad root condition	3	8	
4/19/39	Hendrickson Ave from F.M.H. So. to Park Ave.	20	X		X	371'		Very heavy roots	3	8	
4/19/39	Windsor Ave. from So. Village to a point half way to Park	20	X		X	345'		Very heavy roots	3	8	
4/20/39	Windsor Ave from a point half way bet.Village,Park to Park	20	X		X	345'		Root condition - not bad	3	8	
4/20/39	Center Ave. from Park Ave to Village Ave.	20	X		X	655'		Bad root condition	3	8	
4/21/39	Lincoln Ave. W/S from Lincoln Court to So. Village Ave	20	X		X	165'		Light roots	3	8	
4/21/39	So.Village Ave. from Lincoln Ave. down to Windsor	20	X		X	922'		Heavy root growth bet Lincoln Ave &			
4/24/39	W/S Lincoln Ave from So.Park to Lincoln Court	20	X		X	470'		Center Ave line partly clogged with sand Light roots-line very sluggish	3 3	8 8	
4/24/39	Lincoln Ct. from Lincoln Ave to P.R.W. to So. Village Ave	20	X		X	750'		Light roots-Lincoln Ct..Sewer opposite			
4/25/39	Center Ave. from So.Village to Merrick Road	20	X		X	767'		Lincoln Inn,filled with grease Light roots near Merrick Road	3 3	8 8	
4/25/39	Lincoln Ave. W/S from Merrick Rd. to So.Village Ave.	20	X		X	558'		Heavy root growth near Petitts Bros.	3	8	

COST PER OPERATING DAY - PLANNING - ADMINISTRATION SUPERVISION AND LABOR $ 25.00

Page from Maintenance and Repair Log Book, Revealing Records Kept



Type of Top Root and Knob Which Calls for a Positive Cutter Here the water pressure driven cutter does the job.—See Text.

always be justified. The use of castiron house connections will eliminate much grief for all concerned.

The policy as to sewer connections lays with a governing body of a community, and it is the duty of an officer of a department to bring forcibly, and with clarity, any constructive measures that he recommends. If this is done, he has done his duty to himself and the taxpayer. It is his duty then to carry on to the best of his ability.

One of Our Pets
A prize root which tore away, leaving a five-finger knob on the top inside of pipe —see sketch—which was still a stoppage producer.

Pump Stations

The pump station is the central point to which all gravity lines feed, and it puts us in mind of a large city into which everything pours and straggles, and with positive energy must clear itself to survive. And so in our pump stations, consideration must be given to what comes in and to what extent we must go to dispose of it. The very mention of a pump station brings to us the fact that there is equipment to be considered. Screens, be they bars or baskets or mechanical grinders, have to be kept clean and the mechanism has to be checked regularly for lubrication, wear and tear. Pump and motors should be inspected regularly as to alignment, lubrication—changing old oil and grease at least once a year. Check pumps for clogging. also condition of packing. Pumps should be taken down at least once every five years, if they have run that long without trouble. In that way parts may be replaced at your pleasure and not at some inconvenient time, as an emergency. The conditions under which a pump works more or less determines the time for inspections.

Chlorinating equipment should be inspected for leaking joints; exposed parts should be covered with vaseline; strainers and other parts that clog with salts should be inspected as often as necessary. Under ordinary conditions once every three months is sufficient. Chlorine causes considerable trouble to electrical equipment and the two should never meet. Newly designed stations have a complete separation of the chlorine room from other parts of the building.

The well into which all the sewage flows should be kept clean for at this point sludge and grit settle out and putrifaction and odors set up which become a nuisance to surrounding properties. Daily flushing of a well is the most efficient way of keeping it clean. Any solids or grit which have settled can easily be flushed away with an inch and a half hose and nozzle. While considering the adjacent property owners, it is well to consider the beautification of the grounds and maintenance of the inside and outside of the building. The care of pump stations, if there are enough of them, warrants a utility man whose job it is to keep them in condition.

Costs

The cost of this type of maintenance shows an excellent economy in the form of a satisfied public, and also in dollars and cents. The equipment needed for effective maintenance totals some $2,700, and we plan on replacement every three years. Depreciation and interest runs the equipment cost to about $900 per year for our system. To this must be added $25 per day for 150 days per year to cover planning, administration, supervision, labor—say $3,750 per year.

Based on a coverage of 26 miles (137,280 feet) the cost per foot of sewers cleaned and maintained is—

$$\frac{(150 \text{ days} \times \$25) + \$900}{137.280 \text{ ft.}} = \$0.34 \text{ per foot.}$$

To cover liability, other insurance, and miscellaneous items such as gasoline, water used, etc. The cost may run to 4 cents per foot maximum.

Summing Up

The old method of sewer maintenance, which usually amounted to keeping the fingers crossed until the next call for help is made—then digging up the streets, making repairs, refilling and repaving, resulting in disgruntled taxpayers—is very expensive as against an orderly economic sewer maintenance program. At least such has been our experience in Rockville Center.

For another splendid article on "Sewer Maintenance" see that by J. H. LeChard, Chief Engineer, Atlantic City Sewerage Co., in the Reference & Data Issue of 1939 (May) page 190, and that by E. P. Decher in the Issue of 1940 (April) page 131.

SEWER FLUSHING

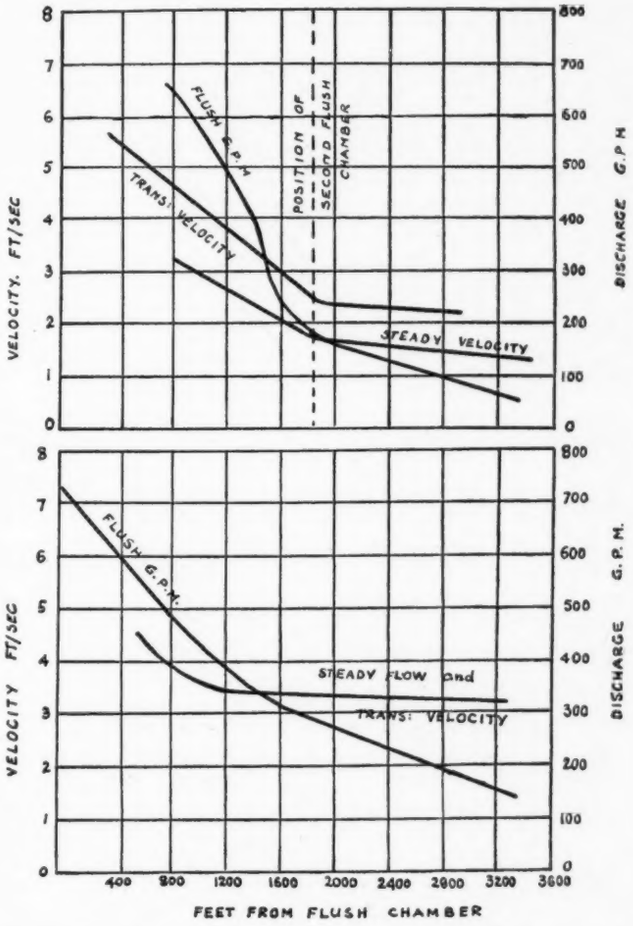
Good and Indifferent Practices

By JOHN D. WATSON
Consulting Engineer, Ruislip, England

This article reveals much pertinent to "Sewer Flushing" practices and presents what may be considered satisfactory flushing and what will prove a waste of effort and funds. The all important depth of flow in flushing, as compared to velocity flow without the needed depth, is pointedly emphasized. If we interpret correctly, many readers will find it necessary to consider some of our existing pseudo-flushing practices as little more than sewer "rinsing," after reading the depth—velocity discussion by Mr. Watson—an authority with a wealth of experience and years of observation to draw upon.

The basic condition upon which calculations for sewer flow should be made is that the sewer have a self-cleaning velocity. In other words, it should never tend to silt up even though the dry weather flow condition persists for long periods while at the same time it must be capable of taking storm water, unless it is wholly diverted from it. Provided they are properly constructed it is not usually difficult to give sewers a sufficient fall for this condition to be fulfilled. Main sewers will work with little or no trouble when laid on a grade of 1:1000 or less and, when the London Main Drainage was designed some 70 years ago, experiments showed that a velocity of 1½ miles per hour was sufficient, and very little cleaning is necessary in these sewers today. They vary from the familiar oval section of 4-ft. x 2-ft. and 8-in. to circular sewers of 12-ft. diameter. They are mainly built of brick.

Trouble is rather more likely to occur in the smaller branch sewers which have to be put in of a size to allow of increasing population so that for perhaps 10 or 20 years, normal flows are insufficient to maintain a self-cleansing velocity; and, while it is usually possible to divert surface water into them, it usually has to be kept out in order to save pumping and purification costs. The system adopted at one time at Hamburg, of constantly flushing the main sewers from a small river, enabled them to be laid at 1:3000, and to be run practically half full continuously, but that principle has rarely been adopted. The usual practice, when artificial flushing is resorted to, being either to provide gates to dam back the flow and then to release the pent up sewage for the purpose; or the use of tanks operated by an automatic syphon, the latter arrangement being as a rule the better one.



Curves Revealing Relationships Between Depth of Sewer Flush (Rate of Flush Discharge) and Effects Down-Sewer

The Great Importance of Depth in Flushing

When arranging for it the important points to bear in mind are, that the flush is not going to be effective over any great distance, and that it is the depth of flow over the invert of a sewer which is the most effective in moving the material which is the main cause of obstruction. That of course, is the condition intended to be provided by the oval sewer, silt being usually the main cause of the trouble in the present connection. In the form of road detritus, though it may reach the sewers mainly in times of storm when there should be sufficient velocity to carry it to the outfall, road detritus in the average condition has been found by experiment to require a velocity of nearly 1-ft./sec. to keep it on the move and if small pieces of broken stone and similar material get into the sewer (which by some unaccountable means they do) such, according to size, will require a velocity of 2½ to 3½-ft./sec. to move them. Incidentally, it is such obstructions in the first instance, as a rule, which cause a general obstruction to build up.

Such material always moves along with a speed of travel less than that of the stream (usually not more than half) and though 2½-ft./sec. flow velocity may move a piece of stone it will only barely do so in 1-in. depth of water. But, if the depth be increased to 6-in. it will roll along quite easily at 2-ft./sec., confirming the contention already made that it is the depth of liquid in the sewer that is the really important factor in keeping it clean. Therefore, the conclusion to be reached, is that, in circular sewers at all events and more particularly in the average branch up to 30-in. dia., the basic cause of silting is *insufficient depth* of flow *rather than velocity;* and, especially is this evident in lateral sewers which only receive intermittent discharges from the dwellings connected to them. Thus, deposits commence which ought to be periodically flushed away because if they are not removed, although they might not immediately render the sewer inactive, they cause a filmy growth (slime) to appear on the pipe wall. This growth in turn further reduces the velocity, and so matters go from bad to worse with the additional evil of the sewage becoming septic and producing large volumes of sewer gas, with its well known attendant evils.

This can be demonstrated in a simple manner by purposely putting some coarse sand or fine gravel in a sewer. Then it will be found that while motion is set up by dragging action, the particles are more or less lifted up into the stream and further motion is carried on by the added effect of suspension. The greater volume of material is naturally carried in the lower layers of the stream, the total quantity being proportional to the depth. Motion, too, will be seen to be from the sides of the sewer towards the centre, the major portion of the suspended matter being carried along the centre of the stream. The amount and the size of the material being carried in suspension

depends upon the velocity of the stream and its depth of flow. But, to a much greater extent depth is controlling, because in appreciable depth of liquid the particles are thrown to a greater height; and, as the velocity of descent of the particles is the same in both cases, the deep stream carries the particle further owing to the greater opportunity of remaining suspended.

Effects of Flushing

The conclusions to be reached, therefore, are that as a general rule it is advisable to provide means for flushing pipe sewers when they are laid at flatter gradients than those listed below:

12-in.....1:300	21-in.....1:600
15-in.....1:400	24-in.....1:700
18-in.....1:500	27-in.....1:800
30-in.....1:900	

Between 2,000 and 3,000 gallons at a flush, according to the size of the sewer and provided it is released once or twice every 24 hours, usually suffice. In any event it should be an amount that, when it does come into the sewer, practically fills it at that point. This, because the depth of the flushing wave near its point of origin decreases as it moves downstream to a point at which the depth and velocity are but little affected by the discharge. As an example, one can consider a 12-in. sewer flush by a 1,500-gallon tank through a 10-in. syphon in 1¼ minutes.

On the accompanying chart the upper set of curves relate to such a sewer laid at 1:630. One curve reveals transmission velocity, the other steady-flow velocity. As regards the former, the rate of transmission, at the commencement of the flush and at different distance from the flushing chamber, is that which would give the maximum scouring velocity, assuming the flush to be discharged into an empty sewer. This velocity lasts but a few seconds and its effect reaches but a short distance. In the matter of the steady-flow velocity, during the period when the maximum volume of flushing water is passing at different distances from the flushing chamber, it will be observed that this velocity lasted for a minimum period of 1 min., the period increasing with the distance from the flushing chamber. There is also a third curve which reveals the maximum volume of flushing water in gallons per minute at different distances from the flush chamber. From this curve, the effect of varying the amount of flush water discharged per minute can be determined. The lower set of two curves, in comparison, relates to a 9-in. sewer having a flush of 750 gallons for one minute.

Facts and Conclusions

The principal facts which become apparent from an examination of these curves are that:

(1)—The velocity dies off rapidly at first until it attains a certain value after which the diminution is small. As a result the flush is transmitted over an appreciable distance, probably about one mile.

(2)—With flat gradients, the velocity when the maximum volume of flush water is passing is less than the rate of transmission at the commencement of the flush, the difference gradually decreasing as the gradient decreases until the velocities are identical—such being indicated by the lower graph.

One can conclude, therefore, that the slope of the advancing flush will gradually flatten as the distance from the flushing chamber increases except where the gradient is sufficient to secure a high velocity. It is noticeable, also, how the steady flow velocity is over 3-ft./sec. at a distance of more than 3,400 ft. from the flush chamber. If, therefore, the sewer gradient is reasonably good, though appreciably less than that above set out, a good flush (rapidly discharged) will keep a sewer clean for at least half a mile even though its capacity be considerably in excess of normal dry weather flow requirements. And that, as already indicated, is the main purpose of artificial flushing.

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

Superintendent Water Works and Sewerage, Greenville, Tenn.

Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing*, a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater, as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots. (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush," causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

SOME SEWERAGE OPERATING KINKS

By A. M. RAWN*

Associate Editor, Water Works and Sewerage

SEWER cleaning operations on a large trunk sewer system give rise to many notions and ideas regarding best methods. The writer presents a few operation and maintenance "kinks" which have been evolved entirely by the field operation forces on the Los Angeles County Sanitation Districts' system. Nothing new is claimed for the ideas and many an operation man may recognize in each, or all, a counterpart of what he daily practices.

Sewer Cleaning

The writer in the October, 1935, issue of WATER WORKS AND SEWERAGE described the use of rubber beach balls for cleaning lines up to 30 inches in diameter. Above 30 inches the balls are expensive and hard to obtain so that for cleaning circular sewers larger than 30 inches in diameter the district forces use a form of "hoe" shown as Fig. 1. It is simply and easily made and can be assembled in the ordinary manhole without much trouble.

In operation the "hoe" is assembled in the manhole and the proper sized flexible belting is attached to its downstream face. Belting is cut and fitted for each size of pipe from 30 inches to 60 inches for circular pipe, and is properly stiffened with sheet metal as is required in the larger sizes. With the exception of the belting attached to the face of the "hoe," the same equipment is used for cleaning all sizes from 30 to 60 inch pipe lines.

Following its assembly in the manhole, the "hoe" is thrust into the downstream pipe and the trail line is attached to the tail board holding the weights. The sewage backing up behind the "hoe" propels it through the pipe, moving any accumulated debris ahead to the manhole below.

The "hoe" is surprisingly efficient in cleaning the sides and invert of the line. Care must be taken to secure a reasonably close fit between the pipe and the outer edges of the belting so that the belting will have to flex forward to permit the escape of water collected behind the "hoe" face. If this precaution is taken, and the tail board is suitably weighted, one may be assured that just about anything movable below the backed-up water line will be shoved or sluiced ahead to the next manhole. Like the pneumatic cleaning ball, described in the October, 1935, issue of WATER WORKS AND SEWERAGE, the "hoe" moves easily over obstructions.

Root Cutting

Many types of root cutters have been manufactured and sold. A number have been tried on the districts' lines. None of them, however, has proven much more efficient than the simple, inexpensive device shown herein as Fig. 2. It is simply and easily made of ordinary butt-welded steel pipe of commercial sizes.

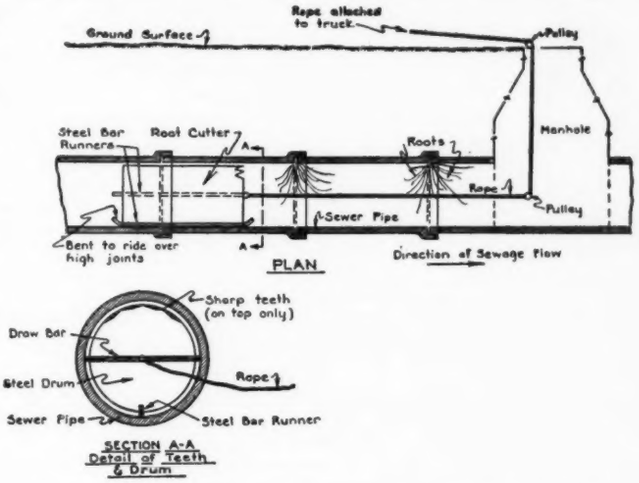


Fig. 2.—Root Cutter for Sewers of 12 to 36 In. Diameter.

*Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles.

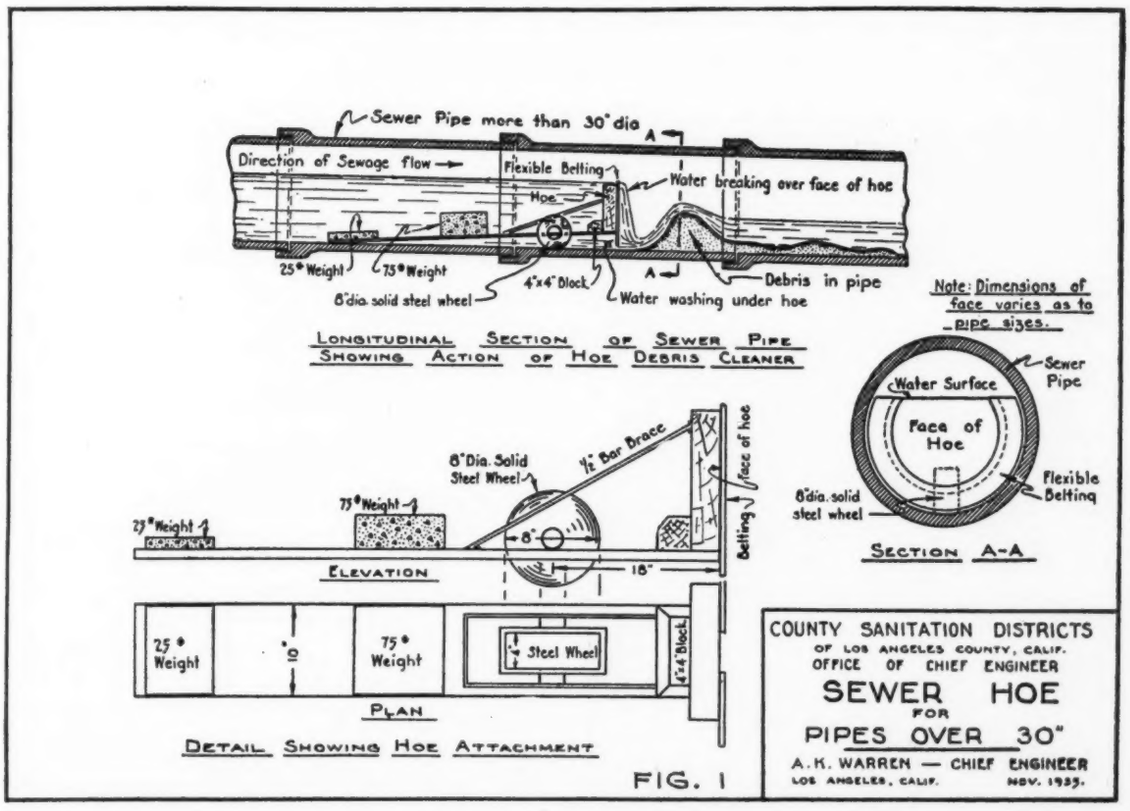


Fig. 1.—The Sewer "Hoe" for Cleaning Sewers Larger Than 30 In. Diameter.

To make it, take a piece of pipe about 18 inches long, serrate and sharpen the edges of both ends, and weld four shoes to the outside of the pipe. Affix halters for the pull and trail lines—and the job is done.

For an 8-inch line job use a 6-inch diameter pipe and ¼-inch strap runners or shoes. For a 12-inch line, use 10-inch pipe. A 12-inch diameter pipe is large enough for a 15-inch line, and so on. The sharpened notches in the pipe ends should be rather deep and wide so that they may pinch and hold the root, tearing or cutting it loose as its point of entrance into the line at which point it is usually quite small and relatively weak.

The pull line is thrust or pulled through with sewer rods, if it cannot be floated through the line. Pulley-blocks are then suitably arranged at the downstream manhole so that pulling may be done with the maintenance truck.

Lacking the proper diameter pipe for an operation, the operation and maintenance crew once manufactured a similar root cutter from a discarded water tank salvaged from a dump heap. It is still used upon occasion.

Air Relief Valve

Fig. 3 illustrates a type of air relief valve used in the 3½-mile (36 in. diam.) effluent pump line leading from the districts' sewage treatment plant. The valve pictured is installed at a summit in the line about 2,000 ft. from the plant where air must be tapped off if the line is to operate efficiently. It is also important that none of the effluent escapes through the blow-off.

A number of valves were tried but all operated with indifferent success until that sketched was installed. As may be seen, it consists of a simple float operating a steel ball valve attached to the end of a section of ½-inch pipe. The ball seats in a ground valve seat tapered to catch and center the ball as it rises. The valve case is constructed from a 5-inch diameter, butt-welded, steel pipe.

The secret of the mechanism is the small hole drilled in the ½-inch pipe near the ball. This is to permit admission of air into the light metal float, equalizing the pressures inside and out on the float and preventing collapse of the thin metal cylinder. When first constructed the hole was omitted and the float promptly collapsed, rendering the valve ineffective. When rebuilt, the air inlet hole was drilled and the valve, operating about three times a minute, has been in continuous service for more than six months.

It may be thought that condensation or spray might eventually fill the float cylinder with water, and the writer admits having shared such a belief at one time. Convinced, however, by the plant chief operator who designed and built the valve, that if the float did eventually fill it could be easily drained and put back into service, the installation was permitted. Now it has been proven that the principle is sound. No water escapes through the valve.

Grease Collection and Incineration

At the district's treatment plant, grease is skimmed manually from the tanks and burned. For a number of years skimmings were accumulated in galvanized iron cans and transported to drainage beds. When drained they were picked up in wheelbarrows and conveyed to the incinerator.

Handling the galvanized iron cans was a dirty and expensive item of labor as was the spreading on drainage beds and the reaccumulation and transportation to the incinerator. The grease draining beds were odorous in spite of all precautions and the incinerator ash was about 90 per cent sand—the latter being picked up with the grease from the beds.

The chief operator requested and received permission to construct the containers and transporting barrow.

The container or pan may be made any convenient size. That shown holds about 3 cubic feet. Placed in the bottom of the pan and standing on a rigid framework which elevates it an inch off the pan bottom, is a ¼-inch square mesh screen, the purpose of which is to provide drainage for the skimmings. The pan is so constructed that all drainage is toward the 1½-inch pipe shown in the right front of the pan at the base. Drainage from the skimmings goes directly back into the sewage tank.

The pan is filled with skimmings as they are taken from the sewage and permitted to drain for a couple of hours before being taken to the incinerator. Twelve such pans are in use

For transporting the pans to the incinerator the pneumatic tire wheel-barrow (illustrated) was constructed and is used. The operator wheels up to the high side of the pan, steps across it and engages the forward cross brace in the two forward pan dogs, then upon lifting the wheel-barrow handles, the rod welded across the back of the pan catches in the two swinging hooks

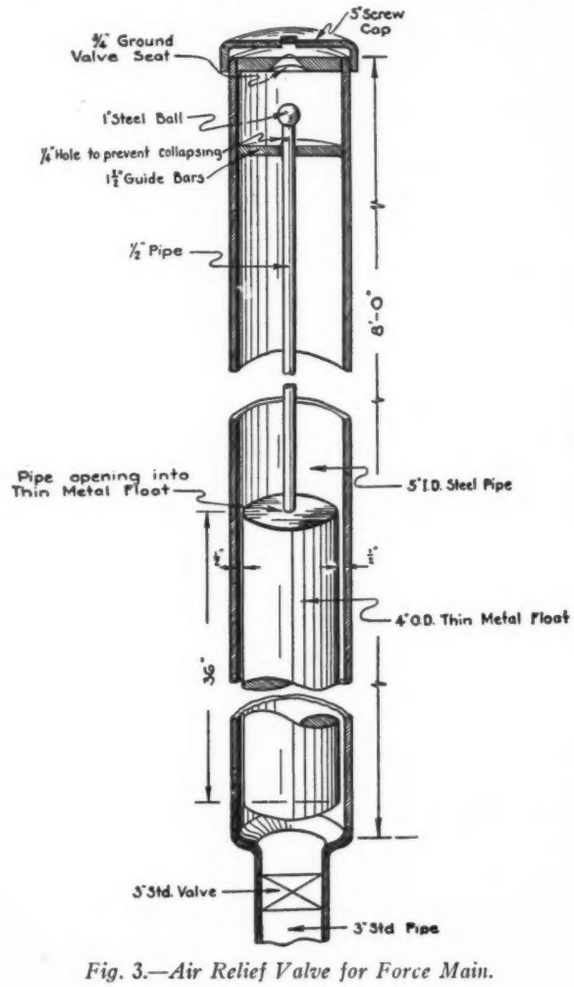


Fig. 3.—Air Relief Valve for Force Main.

attached to the barrow handles, and the load is securely engaged. The penumatic tire prevents wear on concrete walls and cross walks; makes for easy rolling.

It may be seen that when the pan is lifted the slope of the pan bottom is reversed and any water shaken out of the screenings during transportation stays in the pan until it is set down.

At the incinerator a movable sheet metal storage pan is located in front of the charging door. The operator swings the loaded wheel-barrow handles over the storage pan, engages the pan's back rod in the two forward dogs in the storage pan, releases his load and then tips the screenings into the storage pan with a hook.

The pans are cleaned daily with hot water and once a week with grease solvent. The pans and the wheelbarrow were all built in the plant shop by the plant operators.

Wheel Barrow Used for Transporting Skimmings Containers to Incinerator.

TRITURATION OF SEWAGE SCREENINGS

Operating Experiences at Oneonta's Sewage Treatment Plant

By WILLIAM W. WATKINS

Engineer and Supt., Water Works and Sewage Disposal, Oneonta, N. Y.

In November, 1933, Oneonta, a city of about 13,000 people, in Southern New York State, put its new sewage treatment plant into operation. The plant consisted of a mechanically operated bar screen, settling tanks with mechanical sludge removal, separate sludge digestion tanks and glass covered sludge drying beds.

Mechanical Screening

When the plant was constructed, the screen chamber was equipped with a "Rex" Mechanical Bar Screen, supplied by Chain Belt Co. of Milwaukee. This screen was operated automatically by time clocks, set to start and stop the screen mechanism at such intervals as experience had shown to be necessary.

Varying conditions in the sewage flow caused too much head loss through the screen and corresponding changes in velocity in the settling basins, so, in 1935, the screen was equipped with a direct operated single float which resulted in a more uniform flow through the screen and the settling basins.

At Oneonta, as at most sewage plants, the real problem has not been that of *removing* the screenings from the sewage, but that of hygienic *disposal* of the screenings removed.

Screenings Disposal

For four and one-half years—when weather conditions permitted—we dug ditches and carted the screenings out for burial in what the men call the "graveyard"—a piece of city-owned property adjacent to the plant and about 200 yards away from the screen. If too much ditch was dug in the fall it caved in before it was used up. After the ground froze it was economically impossible to dig more ditches until spring. Consequently in the spring it was necessary to spend a week or more with a crew of men and trucks getting rid of the screenings that had been dumped but couldn't be buried.

The daily average of screenings removed has varied widely from a maximum of 33.4 cubic feet to a minimum of 4.43 cubic feet. And on one occasion (not storm flow), the total screenings for one day was 66 cubic feet.

With such erratic quantities of screenings it was necessary to keep a large amount of open ditch available at all times, as the operator did not have time to dig his own ditches as required. In addition to the extra cost of ditching it was necessary to have a small truck convenient at all times in order that the full cans of screenings might be emptied and not allowed to accumulate for too long periods.

Burying the screenings took about 2 hours of the operator's time, besides the extra help for ditching and the cost of the truck, making the total cost of handling the screenings about $2.00 per day. Since there is no definite relation between sewage flow and screenings handled, costs per million gallons have little meaning, and therefore have not been recorded.

Early in 1937 it was decided that the cost of handling screenings was too high and that something must be done. In coming to this decision, the element of nuisance admittedly had a bearing. After a survey of the field for satisfactory equipment for shredding or macerating screenings for treatment with the sewage, a "Rex Triturator," manufactured by the Chain Belt Company of Milwaukee, was purchased, and installed in June, 1937, for shredding all screenings removed by the automatic bar screen.

The "Triturator" has been operated every day since its installation. It has saved time for the operator, money for the city, and has gotten results in digestion that we had not expected, but which are very gratifying. The digester gas yields have revealed greater uniformity and higher values, consistently.

Benefits from Trituration

From an operating standpoint, the time required by the operator for putting the day's screenings through the Triturator is about one-half hour to one hour—instead of the two hours or more formerly required to bury the screenings. The operator has the saved time to devote to less objectionable and more valuable duties.

From a sanitary or cleanly standpoint, there is no comparison between the old and the new methods. There are now no cans to fill up, to slop over in trucks, to be washed up when empty, or left to draw flies.

From a strictly monetary standpoint, trituration of screenings shows a money saving benefit which can be actually measured. Some of these follow.

The cost of ditching is eliminated. The use of a truck is no longer necessary. These combined items have figured $1.73 per day at Oneonta. Against this is the cost of power and water consumed by the Triturator. Maintenance is not figured in either case, because such has been negligible. The operator has at least an hour more time available each day, and has been able to do some of the work for which we formerly had to hire extra help from time to time.

At an estimated consumption of 25 gallons of water per minute and forty minutes' operation per day, the cost of water at current retail rates is 13 cents per day. A five horse power motor, running at full load, will consume about 4.5 K.W.H. per hour. This figures twenty-eight cents per day at current rates paid. This makes a total additional cost of forty-one cents per day, not counting in depreciation and interest charges.

Gross Savings by Trituration	$1.73
Less power and water cost	.41
Net savings by Trituration (per day)	$1.32

Operating Cost and Savings

From the time that the plant was put in operation until the Triturator was installed, the average daily quantity of screenings has been 12.88 cubic feet. While there is no way of measuring the screenings, it is reasonable to assume that the same average would still hold. To arrive at the cost per cubic foot of triturating screenings, the maintenance cost will have to be estimated, as there has been no maintenance yet except the resharpening of one set of teeth, ten months of service and feeding to the Triturator all materials removed by the bar screen.

Re-sharpening teeth and reserve for parts replacement	$ 22.00
Water cost per year	48.87
Power cost for year	102.20
Time of operator	124.00
Depreciation at 10% per year	79.00
Total yearly cost	$375.07
Average daily cost	1.03
Total cost per cu. ft. screenings	0.08
Gross yearly cost of burying screenings	$813.00*
Gross yearly cost of triturating screenings	375.07*
Net saving by trituration (per year)	$437.93

*Including operator's time.

This means that the savings will have paid for our Triturator in less than two years' time.

Increased Gas Production

In the ten months since the Triturator was installed, gas production has averaged 7,262 cubic feet per day. The production in the corresponding preceding ten months was only 3,022 cubic feet.

When the weight of screenings is considered in relation to the total amount of settleable solids in the sewage, triturated screenings reaching the digester must be given credit for a calculated 50 per cent of the gas increase, if not more.

From this writer's experience, it can be said, with emphasis, that the successful shredding or grinding of screenings is one of the outstanding advances in sewage treatment of the past five years. No simpler disposal can be imagined than the grinding and return of all screenings to the sewage.

GRIT REMOVAL*

Some Fundamental Factors in Grit Separation and Grit Chamber Design

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New York

IT IS our aim in this paper to offer what we believe to be pertinent considerations in grit separation, and a rational method for designing sewage grit chambers. The method advocated is based upon our own observations over a period of more than twelve years, and has been checked and re-checked in our research laboratories under controlled conditions at flows approximating those dealt with in plant operation.

We shall not discuss the need for grit chambers, because the advantages of such units in modern sewage treatment practice has already become so well recognized that grit removal is being extended even to the smaller plants, including those assumedly receiving domestic sewage only.

The purpose of this paper is to recommend basic standards of grit chamber design, as follows:

1. To fix the minimum size of grit particle to be removed.
2. To determine the appropriate dimensions of a grit chamber, based upon the settling rate of particles of such minimum size.
3. To establish a means for determining the qualities of satisfactorily washed grit.

It is our belief that if the designing engineer will follow and apply the design standards, which are developed from what is to follow, he will have every assurance that plant operating results will meet the objectives set.

The Need for Correct Specification

For twenty-five years or more the practice has generally been to design sewage grit chambers on the basis solely of velocity and detention. Research studies reported in this paper, plus critical analyses of many grit chamber installations, have led us to the conclusion that this basis of design is incorrect. Instead, we are strongly of the opinion that *area is the primary governing factor,* rather than velocity and detention.

There is, we believe, a definite need for unanimity on this matter of the importance of area and on a specification that not only takes area into consideration but also gives heed to other considerations, such as the following:

1. The subsidence chamber should be designed to collect all grit coarser than a definite size—to-wit, at least that coarser than 65 mesh, and in certain cases, that coarser than 100 mesh.
2. The grit removed should be essentially free of putrescible or washable organic matter. It should contain not more than 3 per cent of such material.
3. The cleaning mechanism should deliver the grit thoroughly drained of its free water, so that it may be readily handled and disposed of.
4. The chamber should be designed to handle expected flows at a minimum loss of head. And, it should operate under widely varying flows without requiring adjustments.
5. The collecting chamber should perform all functions without unsightliness, the septization of deposited solids, or the liberation of foul odors.

All of these desiderata are readily obtainable if basic, and demonstrable factors in design are followed. It remains only for the designing engineer to insist on a high level of grit-chamber operation, as has already been done in the case of other units such as sedimentation tanks, digesters, trickling filters, etc.

What Is Washed Grit?

The term "washed grit" will frequently be used in this paper. Let us, therefore, briefly consider the term, and what we consider it to mean.

A method commonly used for determining the percent putrescible or, rather, washable organic content of grit employs the so-called "Dazey Churn" test as described in *Sewage Works Journal,* July, 1930, p. 355. This test provides a means for washing the grit sample free of sewage solids which would create a nuisance, and for determining their weight relative to the weight of the grit sample. While the "Dazey Churn" test may be subject to some criticism, the results of many tests have proved it a simple and reliable method for determining whether the grit may be safely spread above ground, or had better be buried or burned to prevent nuisance.

Samples of washed grit from 23 plants have recently been analyzed for putrescibles. Of these, 18 samples or 79% had less than 3.5% putrescibles. All of the latter were clean, odorless and entirely safe to spread on the ground surface.

The remaining five samples showed from 5 to 8.7% putrescibles. Most of these were not typical grit. While they had no odor to speak of, they contained large quantities of trash such as water logged sticks, leaves, and seeds. It is interesting to note that although one sample was apparently clean it showed 7.3% loss in weight after washing. This grit contained a large quantity of inorganic slimes. Another sample containing only 5.5% putrescibles was definitely objectionable on all counts.

The results of these tests seem to indicate that typical grit containing not over 3.5% putrescibles should be generally satisfactory for disposal around the plant. However, washed grit containing less than 1% of putrescible organics can be obtained in many instances where careful attention is given to the design and operation of grit chambers. It is expected that recommendations will soon be made for revising the "Dazey Churn" test procedure in such manner that non-putrescible organics may be accounted for separately.

Inadequacy of Rule-of-Thumb Design Method

A common rule-of-thumb method for designing grit chambers is to provide for a 60 second detention at an average velocity in the channel of 1 foot per second at maximum flow. Usually no consideration is given to the size of grit particles to be removed, settling characteristics of the grit, or the effect of area on the efficiency of the grit chamber. Mechanisms of various kinds are used to continuously remove the deposited material, after which it is sometimes washed and sometimes not. When it is not washed, a major operating nuisance is almost invariably experienced.

Investigators* have concluded that the size of grit particles which cause the most trouble in sewage plants are those of 65 mesh (0.20 m.m.) and coarser, and that complete removal of practically all 65 mesh grit from the system is an essential objective in good grit chamber design. In some cases it is desirable to design for the removal of finer than 100 mesh. Such, for instance, is the case where aeration channels for grease removal follow the grit chambers.

A study in the field shows that few plants designed on the rule-of-thumb principle referred to above, are removing anything approaching all of the +65 mesh inorganics, not to mention the +100 mesh. This is strikingly notated in Fig. 1, where the curves plotted denote the distribution of grit sizes at 21 sewage treatment plants.

Starting Anew with the Old Theory of Free Settling

If, then, the rule-of-thumb method leaves much to be desired on the score of accuracy, what shall we consider as a substitute? Obviously, this is a matter of going back to fundamentals and building anew on a different basic concept. As a starter, we have taken the theory of "Free Settling" as enunciated years ago by Professor Richards, and applied successfully in other fields where fine inorganic solids suspended in water must be dealt with.

The general principles of free settling of solid particles in liquids as established by such authorities as Richards and others, state that under free settling conditions the rate of falling particles depends, other factors being equal in each case, upon:

Specific Gravity. Of two particles having different gravities, that having the higher will fall faster.

Size. Of two particles of the same specific gravity, the larger will settle faster.

The specific gravity and size have a further effect upon the rate of acceleration of the particles during the time they are acquiring their full velocity, that is, before they reach the point where the friction of the water, plus the force of the rising current, if there be any, balances the force of gravity. This

*This paper was one of a group of three on the same topic presented November 29, 1939, before the Sanitation Group of the American Society of Mechanical Engineers in New York City.
**Deceased.

*A.S.C.E.-Transactions, Vol. 91, p. 495 (Dec., 1927), "Grit Chamber Practice—A Symposium."

effect is that, of two particles which are equal-settling, the smaller particle with higher specific gravity reaches its full velocity more quickly than the larger particle with lower specific gravity or, in other words, it has greater acceleration.

Shape. Of particles which just pass through the same screen, the round grain settles faster than the long, narrow grain, and the latter settles faster than the flat grain.

Other conditions which affect the settling of particles are air bubbles, grease, magnetic characteristics, and the density and viscosity of the liquid.

Richard's theory relates to quartz (2.65 sp. gr.) grains settling in still water. Grit chamber operation deals with the settling of grains of about the same specific gravity in a stream of sewage flowing at rates from 0.3 to 1.2 feet per second. Studies made at our Westport (Conn.) laboratory, which will be discussed in greater detail later, indicate that similar sized particles settle according to Richard's theory, regardless of whether the water is in a quiescent state or in motion. This is clearly brought out in Fig. 2 where the two curves, representing rates of settling under the two conditions, are almost identical.

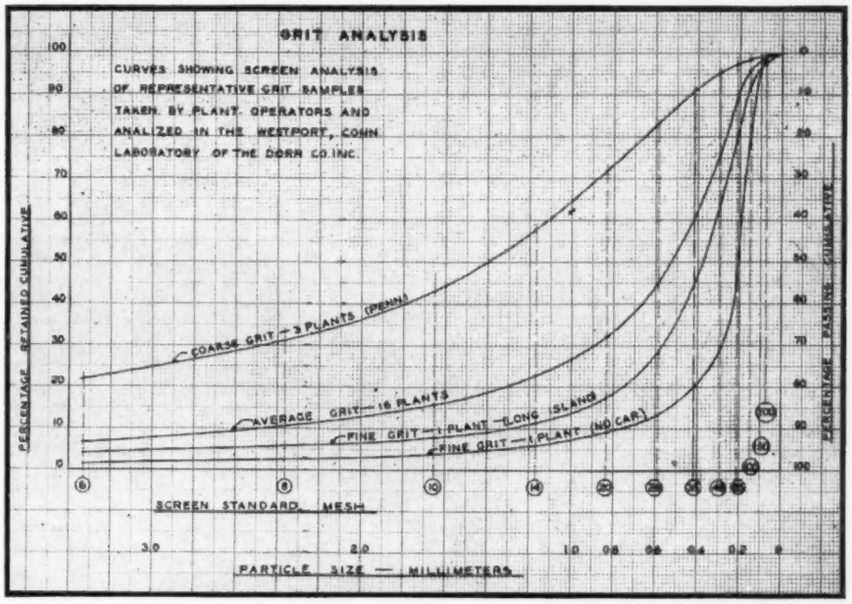

GRIT ANALYSIS
CURVES SHOWING SCREEN ANALYSIS OF REPRESENTATIVE GRIT SAMPLES TAKEN BY PLANT OPERATORS AND ANALYZED IN THE WESTPORT, CONN. LABORATORY OF THE DORR CO. INC.
PERCENTAGE RETAINED CUMULATIVE
PERCENTAGE PASSING CUMULATIVE
COARSE GRIT — 3 PLANTS (PENN.)
AVERAGE GRIT — 16 PLANTS
FINE GRIT — 1 PLANT LONG ISLAND
FINE GRIT — 1 PLANT (NO CAR.)
SCREEN STANDARD MESH
PARTICLE SIZE — MILLIMETERS

Fig. 1—Sieve Analysis of Representative Sewage Grit From Twenty-one Plants

Some Deductions from Theory as Applied to Practice

Using the settling rates plotted in Fig. 2 we have made some deductions with respect to the paths traced by particles of various sizes while settling in streams of water flowing at several velocities experienced in grit chamber practice. These paths are shown graphically in Fig. 3.

The horizontal lines (depths of flow) may be taken to represent the bottoms of grit collecting tanks of various depths. The diagonal lines represent the settling paths of particles of various sizes at the indicated velocity of flow. The particle size appears on the diagonal and the velocity at the end of each line. The settling paths of 48, 65 and 100 mesh particles are shown for velocities of flow of 0.4, 0 6, 0.8 and 1 foot per second. For each of the four velocities the horizontal scale reveals the distance that a particle of given size must travel horizontally before it will have settled to the depth appearing on the left verticle scale.

Theory of Grit Chamber Design

From the foregoing we may state the following theory:

"A sand grain suspended in a liquid tends to settle at the same velocity with reference to the surrounding fluid, regardless of whether the body of liquid is at rest or is moving in a horizontal direction."

It has been determined that the size of sand particles ordinarly present in any appreciable quantity in domestic sewage lies within a range of 0.10 m.m. (150 mesh) to 0.83 m.m. (20 mesh) diameter. The settling velocities of quartz grains, within these limits, have been determined in bodies of water flowing horizontally at velocities of 0.3 to 1.25 ft. per second. At velocities above 1.25 ft. per second, the sand grains cannot come to rest on a flat surface as they are caused to slide along the bottom by the high velocity of flow. At velocities below 0.3 ft. per second, settling conditions are practically the same as in still water.

Where the stream is subjected to agitation just ahead of the grit chamber there is, of course, a certain period of time required for the grit particles to reach their terminal (maximum) settling rate, but this time element is so short that it can be neglected in practice. Once the maximum or terminal velocity of fall has been reached, settlement continues at a constant rate thereafter. Settling particles, therefore, take a diagonal path which is the resultant of the horizontal force, due to the sweeping stream, and the vertical force exerted by gravity.

Application of the New Theory to Common Types of Grit Chambers

Let us now see what happens in the usual types of grit chambers according to the new theory which we have just deduced.

Referring to Fig. 4, the diagonal line represents the path of

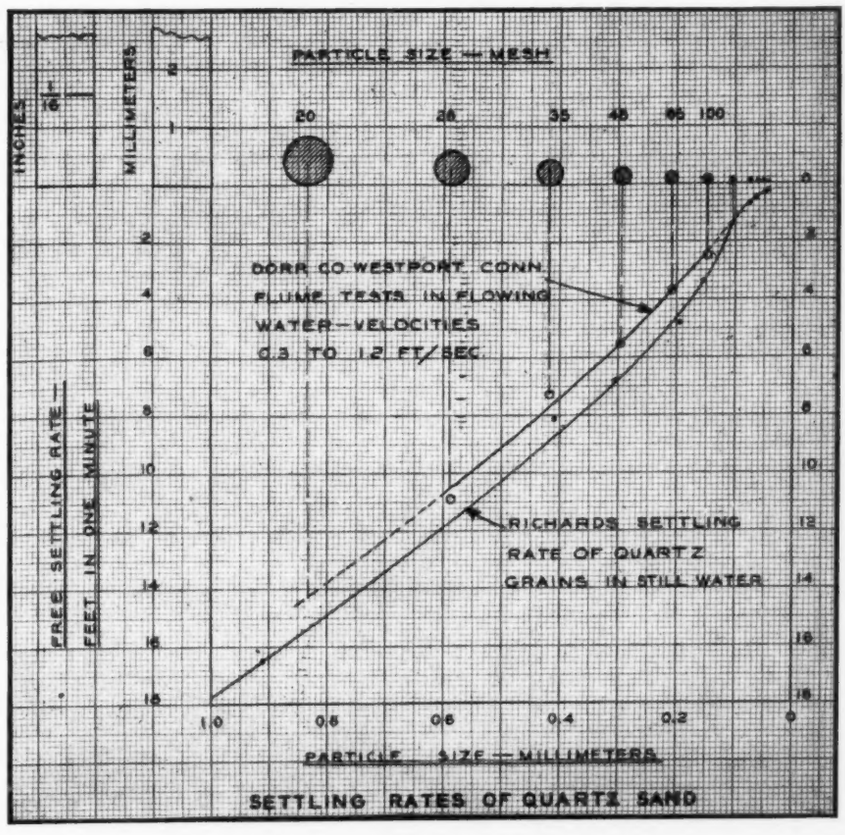


Fig. 2—Settling Rates of Quartz Sand Grains
Comparing Observed Rates in Still Water and in Flume Flows at Various Rates.

a 65 mesh particle of quartz under the influence of a velocity of stream at 1 ft. per second and a detention period of 60 seconds.

In most cases there will be turbulence in the influent channel so that the dispersion of sand grains throughout the liquid will extend from practically the surface to the floor of the channel. This applies particularly to the finer material, such as 65 and 100 mesh. If we start by assuming that all 65-mesh particles enter the subsidence chamber at the water surface, we are looking to securing the most conservative design, and, thereby, the minimum number of such particles reaching the outflow end of the chamber.

Diagrammatic outlines of the floor levels of grit chambers of varying depths are shown by F, G, H, I and J. All of these grit channels of trial design are 60 ft. long and in each case it must be assumed the width of the tank is to be adjusted to provide a stream velocity of 1 ft. per second for the indicated depths on the studygraph. For the purpose of illustration we will assume that the designed flow is 11.0 m.g.d. (17 c.f.s.).

Following the diagonal path of settling line it is revealed that tanks F and G would be longer than necessary to remove the 65-mesh grit. In I and J, the 65-mesh particles entering at the surface would not reach the bottom within the tank bounds. It will be readily seen that this condition is aggravated as tank depth is increased. In H, the end of the tank and the floor of the tank both intersect the diagonal settling path, indicating that 3 ft. 6 in. depth is correct for this flow.

From this base the necessary tank width is calculated. By referring to the table in the upper right-hand corner, the width of this 60 ft. tank is 4 ft. 10 in. and the area of Tank H is 291 sq. ft. That the area is an important consideration becomes apparent later.

This diagrammatic presentation shows that the "1 ft. per second —60 seconds detention" method for designing grit chambers has definite limitations. No satisfactory design can be established without first considering the settling rate of the *minimum* particle size to be removed.

Fig. 5 is similar to Fig. 4 insofar as the basic conditions of particle size, rate of flow and detention are concerned. All the grit chambers tabulated in the upper right-hand corner have one characteristic in common—the same surface area of 289 sq. ft.—while the common characteristics of those tabulated in Fig. 4 was length, 60 ft. The longitudinal cross-sections, lettered A, B, C, D and E, are shown of the correct lengths for individual depths, from 1 to 5 ft. inclusive.

Note the correlation between Figs. 4 and 5. In Fig. 4 the surface area of the correctly designed tank "H" was 291 sq. ft.; in Fig. 5 it proves to be 289 sq. ft. Apparently, then, surface area is a vitally important consideration in correct grit chamber design.

Area the Determining Factor in Design

In order to check our hypothesis with respect to the importance of surface area, another relationship has been drawn up in Fig. 6. The graph is similar to Fig. 5 with the exception that the particle settling path is in a stream having a velocity of 0.6 ft. per second rather than 1 ft. per second. In this case the tank widths have been re-adjusted to provide a cross-section area which will give 0.6 ft. per second for the varying depths shown.

The areas, 289 sq. ft., indicated in the table in the upper right-hand corner are the same as those for velocities of 1 ft. per second in Fig. 5 and for curve "H" in Fig. 4.

The fact that the diagonal path which a particle follows is a straight line is of considerable significance. It means that if the velocity is halved, the particle will settle out in half the distance, so, with a tank one-half the depth and width sufficient to secure one-half the velocity, the particle will settle out in half the distance. With these facts established, it may be stated:

"The capacity of a grit chamber is in direct proportion to the area, regardless of the relation of width, depth, and velocity."

This statement is based on the assumption that the chamber in question is of rectangular shape and that the velocity of flow is uniform. The truth of the above statement can best be proven mathematically as follows:

Let:

F = Flow in cu. ft./second.
Q = Flow in M.G.D.
W = Width of channel in ft.
L = Length of channel in ft.
D = Depth of channel in ft.
V = Velocity of stream in ft./sec.
X = Settling rate of particle in sec./ft.
A = Surface area of channel in sq. ft.

Then

$$F = WDV \qquad (1)$$

$$D = \frac{L}{VX} \qquad (2)$$

$$A = WL \qquad (3)$$

$$F = 1.5Q \qquad (4)$$

Substituting (2) in (1)

$$F = \frac{WVL}{VX} \text{ or } F = \frac{WL}{X} \qquad (5)$$

Substituting (3) in (5)

$$F = \frac{A}{X} \text{ or } A = FX \qquad (6)$$

Substituting (4) in (6)

$$A = 1.50QX \qquad (7)$$

Therefore, the area required per MGD is

$$A = 1.5X \qquad (8)$$

or the area required per cu. ft./sec.

$$A = X \qquad (9)$$

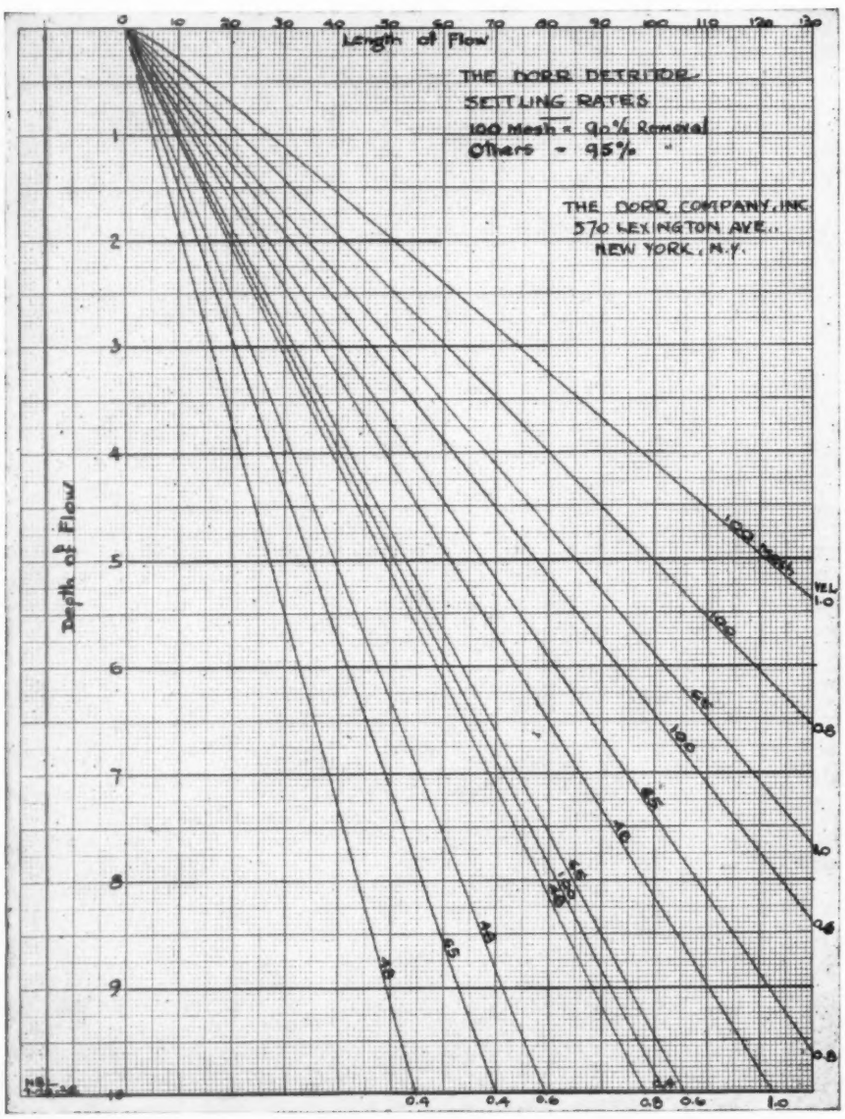


Fig. 3—Paths-of-Settling of Particles of Representative Sizes of Sewage Grit in Characteristic Grit Chamber Velocities.

Derived from the above are:
Given length and velocity to figure depth

$$D = \frac{L}{VX} \qquad (10)$$

Given depth and velocity to figure length

$$L = DXV \qquad (11)$$

Given length and depth to figure velocity

$$V = \frac{L}{DX} \qquad (12)$$

Given width to figure length

$$L = \frac{A}{W} \qquad (13)$$

Given length to figure width

$$W = \frac{A}{L} \qquad (14)$$

It will be seen that in (5) the velocities cancel out, leaving the capacity a function solely of width and length or area and settling rate of particle. For these reasons a *grit chamber may be made of any shape desired,* so long as the area is sufficient. Having established area as the determining factor in the design of sewage grit chambers, the maximum overflow rates for practically complete removal of various size particles may now be tabulated.

Mesh	Overflow Rate*
35	73,000
48	51,000
65	38,000
100	25,000

(*Gals./day/sq. ft. area)

For example, a flow of 11 m.g.d. would require a grit chamber surface area of $\frac{11{,}000{,}000}{38{,}000}$ = 289 sq. ft. in order to remove practically all 65 mesh and coarser grit.

Relation of Particle Size to Settling Area of Five Grit Chambers in Operation

In order to illustrate the relationship of settling area to particle size, we will refer to results derived from operating data from three representative grit chambers designed on the old basis of velocity and detention alone. The particle sizes retained and the sizes passing through agree with our area-capacity relationship. We shall also comment on two grit chambers having design features of special interest.

Early Type of Grit Chamber

The first is an early single channel grit chamber designed to handle a maximum flow of 25 m.g.d. in each channel. Present storm flows are reported to be 14 to 28 m.g.d. The channel, according to our claims, should be deficient in settling area since a consideration of length and depth indicates it capable of removing only coarse grit, 48 mesh and larger, even at velocity of 0.7 ft. per second.

Under the head Grit Chamber "A," is a typical screen analysis of grit removed by this chamber, as supplied us by the plant operator. Note that 96% of the particles collected were retained on a 50-mesh screen. Deposits of fine grit appear in the primary sludge and digesters.

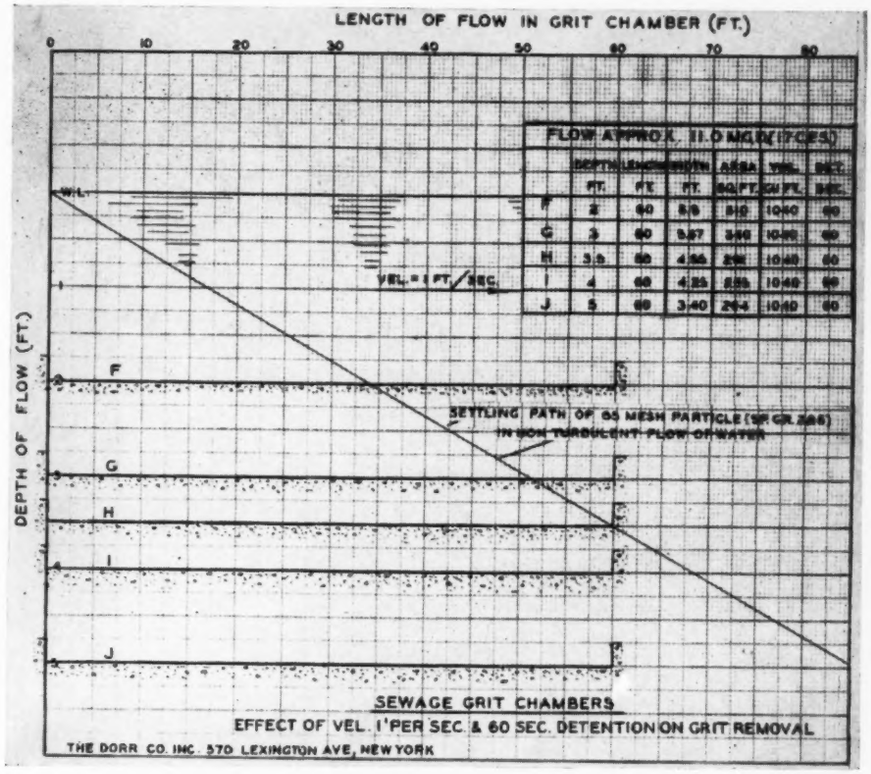


Fig. 4—Chamber Design—Study No. 1.
Observing the path of 65 mesh grit through chambers having a common length but various combinations of width and depth to secure a common detention of 60 seconds at a velocity of 1 ft./sec. in all five designs. Thus revealed is the high importance of surface area in contrast with cross sectional area, or velocity.

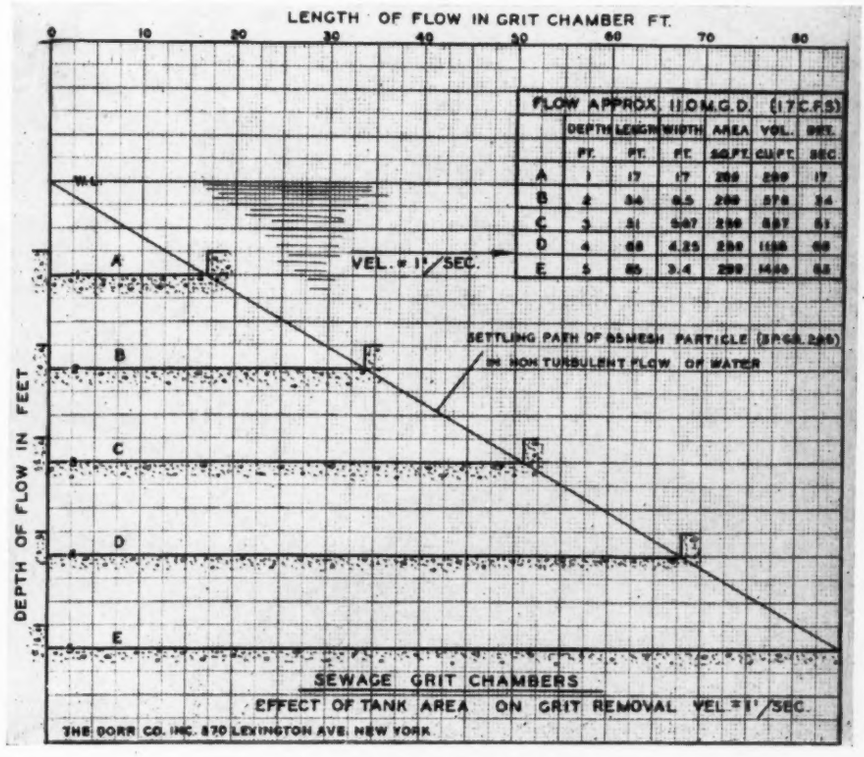


Fig. 5—Chamber Design—Study No. 2.
In which the factors in common for the 5 chambers are surface area and the 1 ft./sec. velocity of flow. Taken with Fig. 4 this graphical study also reveals the high significance of surface area in contrast with other dimensions.

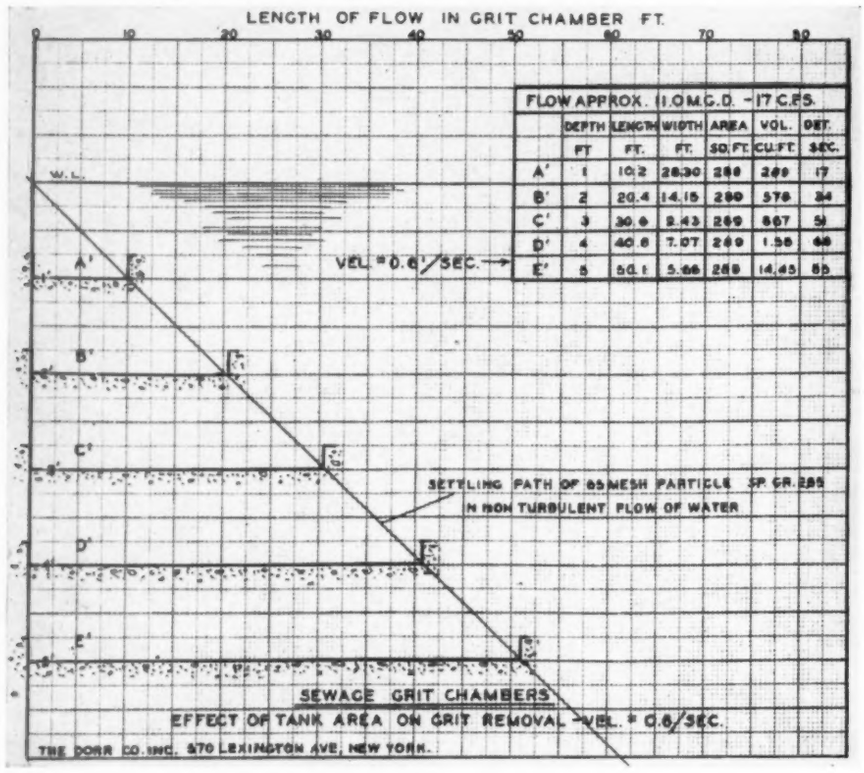

LENGTH OF FLOW IN GRIT CHAMBER FT.
0 10 20 30 40 50 60 70 80
FLOW APPROX. 1.0 M.G.D. - 1.7 C.F.S.
DEPTH LENGTH WIDTH AREA VOL. DET.
FT FT. FT. SQ.FT. CU.FT. SEC.
A' 1 10.2 28.30 288 289 17
B' 2 20.4 14.15 288 576 34
C' 3 30.6 9.43 288 867 51
D' 4 40.8 7.07 288 1.156 68
E' 5 50.1 5.66 288 14.45 85
W.L.
VEL. = 0.6'/SEC.
SETTLING PATH OF 65 MESH PARTICLE SP. GR. 2.65
IN NON TURBULENT FLOW OF WATER
SEWAGE GRIT CHAMBERS
EFFECT OF TANK AREA ON GRIT REMOVAL - VEL. = 0.6/SEC.
THE DORR CO. INC. 570 LEXINGTON AVE. NEW YORK.

Fig. 6—Chamber Design—Study No. 3.

Here the same common surface area, that proven the correct selection in Figs. 4 and 5, is employed in studying the effect of 0.6 ft./sec. velocity on the settling path of 65 mesh particles.

More Recent Type Chamber

The second unit is a twin-channel chamber in a recently constructed plant. Each channel is designed for a maximum flow of 40 m.g.d. Effluent connections are fitted with adjustable gates which operate as submerged weirs.

The channels are deficient in settling area and operated at a velocity of 1.25 ft./sec. are capable of removing only coarse grit coarser than 48 mesh particles. As a result grit deposits in the digesters are marked. Under heading Grit Chamber "B" appear a typical screen analysis of grit taken from the digesters.

Double Channel Chamber

The third unit is a multiple channel chamber, each channel being designed to handle a constant flow of 90 to 100 m.g.d. received from raw sewage pumps. The chamber discharge is through large submerged gated openings.

These channels have a settling area capable of removing coarse grit up to and including a portion of the 48-mesh particles at velocities between 0.75 and 1.05 ft./sec. Considerable fine grit has been found in the plant beyond the grit chambers. According to analysis of the grit that passes the grit chambers, 80% is between 40 and 80 mesh. See analysis under heading Grit Chamber "C."

Grit Chamber "A"
(Vel. = 0.7 ft./sec.)

Typical Sieve Analysis of Grit Deposited

Through 30	56%
Through 30 On 50	40%
Through 50 On 60	3%
Through 60 On 150	1%
Volatiles (dry basis)	10.2%
Putrescibles	0.8%

Grit Chamber "B"
(Vel. = 1.25 ft./sec.)

Sieve Analysis of Grit Taken from Bottom of Sludge Digestor

On 28	6.2%
Through 28 On 48	54.0%
Through 48 On 100	23.0%
Through 100	10.0%

Grit Chamber "C"
(Vel. = 0.75 to 1.05 ft./sec.)
Sieve Analysis of Typical Grit

(a) Retained in Chamber.

On 5	20.5%
Through 5 On 10	15.0%
Through 10 On 20	24.5%
Through 20 On 40	25.0%
Through 40 On 60	10.5%
Through 60	4.5%

(b) Passing Through Chamber.

On 20	1.4%
Through 20 On 40	2.3%
Through 40 On 60	9.4%
Through 60	86.6%

Deep Weir Wall Type

Following the same procedure as in the three cases above we have made a diagramatic analysis of a grit chamber designed to handle 169 m.g.d. constant flow, received from raw sewage pumps—See Fig 7. The design is interesting because of the unusual water depth and the use of a deep weir wall at the discharge end.

The diagram indicates that at a velocity of flow of 1 ft./sec. these channels have a settling area capable of removing only the coarse grit, 35 mesh and larger and, possibly, a portion of the 48 mesh grit.

Since capacity of grit chambers is a function of surface area, the extra depth is of no value. The deep pocket formed at the weir wall might even prove a handicap. To date no operating data has become available to confirm our conclusions based on the graphic analysis.

Although the line of settling of 65-mesh grit strikes the end wall, we are of the opinion that a great deal of the grit will be carried up and over the wall, due to the upward current caused

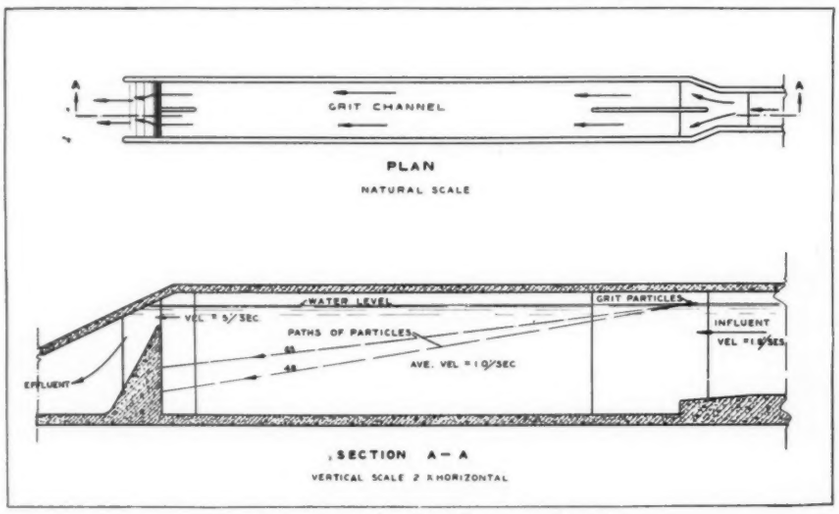


Fig. 7—Deep Weir-Wall Type of Chamber.

This diagram indicates the lack of value of great depth in retention of grit of 65 mesh and finer when the velocity is 1 ft./sec. The settling area proves to be deficient.

by interception of the main flow. It will be interesting to observe whether or not coarse grit tends to pocket at the weir wall and, further, whether or not the extra depth adds to the sewage solids to be washed from the grit collected.

Proportional Weir Type

Another recently built unit (Fig. 8) makes use of a proportional weir at the discharge end of the channels to automatically control velocity of flow. The attempt of the engineer is to prevent deposition of sewage solids by holding the velocity of flow at about 1 ft. per second, while the depth of flow may vary. There are a number of points about this design that are of interest. We find the settling area to be sufficient to remove coarse grit, 48 mesh and larger, assuming uniform flow conditions through the channel.

In the diagram, lines of settling have been drawn for a 65 and 48-mesh grit particle located near the water surface at the entrance end of the channel. Because the chamber is deficient in settling area, the normal path of 65-mesh particles does not intersect the bottom. The normal path of the 48-mesh particle does intersect near the discharge end; but what effect the proportional weir may have on the ability of the particle to drop out of the line of converging flow to the weir is something of a question.

Velocity of flow at entrance to the chamber is 4 ft. per second. Computed average velocity within the chamber is assumed to be 1 ft. per second. Velocity of discharge through the wide bottom slot of the proportional weir can be computed at 16 ft./sec. What the actual velocity of flow conditions are near the bottom of the main chamber due to influences of these control features, remain problematical.

Scale model studies in our hydraulic laboratory at Westport have shown that after an hydraulic balance is established, flow velocities persist throughout the liquid even though the total energy of flow may be computed to be quite insignificant.

We have noted the persistence of flow in large settling tanks, even where very low velocities are involved. The reader has probably seen the movement of underwater cloud banks of activated sludge or chemical floc in settling tanks. With these observations in mind, we wonder if the proportional weir instead of lending to the efficiency of channels for collection of grit, does not actually reduce the effective area and would be better out than in.

Flume Tests to Determine New Design Factor

While much had been published on the settling rates of various substances in quiscent liquids, there was very little information available on the settling characteristics of free falling materials in flowing streams. In consequence, a series of flume tests was begun at our Westport laboratory in order to secure basic design data under actual large-scale flow conditions.

The flume was built with an intake from a river and was equipped with a baffled stilling box at the head end. The flume was 45 ft. total length, 41 in. total depth, by 17½ in. width inside. It was equipped with an adjustable rectangular weir at the downstream end. To prevent eddy currents, the bottom of the flume was divided into sections 5 ft. long by installing thin riffles, wedge-shaped in cross-section. Each riffle section had a plugged drain hole, the entire flume being built of finished tongue and groove lumber.

Carefully weighted, uniform samples of wet sand were gently sifted into the head end of the flume at the water surface in a manner to prevent plunging. After a time of such application, the flume was slowly drained and the deposit from each of the 5 ft. sections was carefully removed. Recovered sand was dried

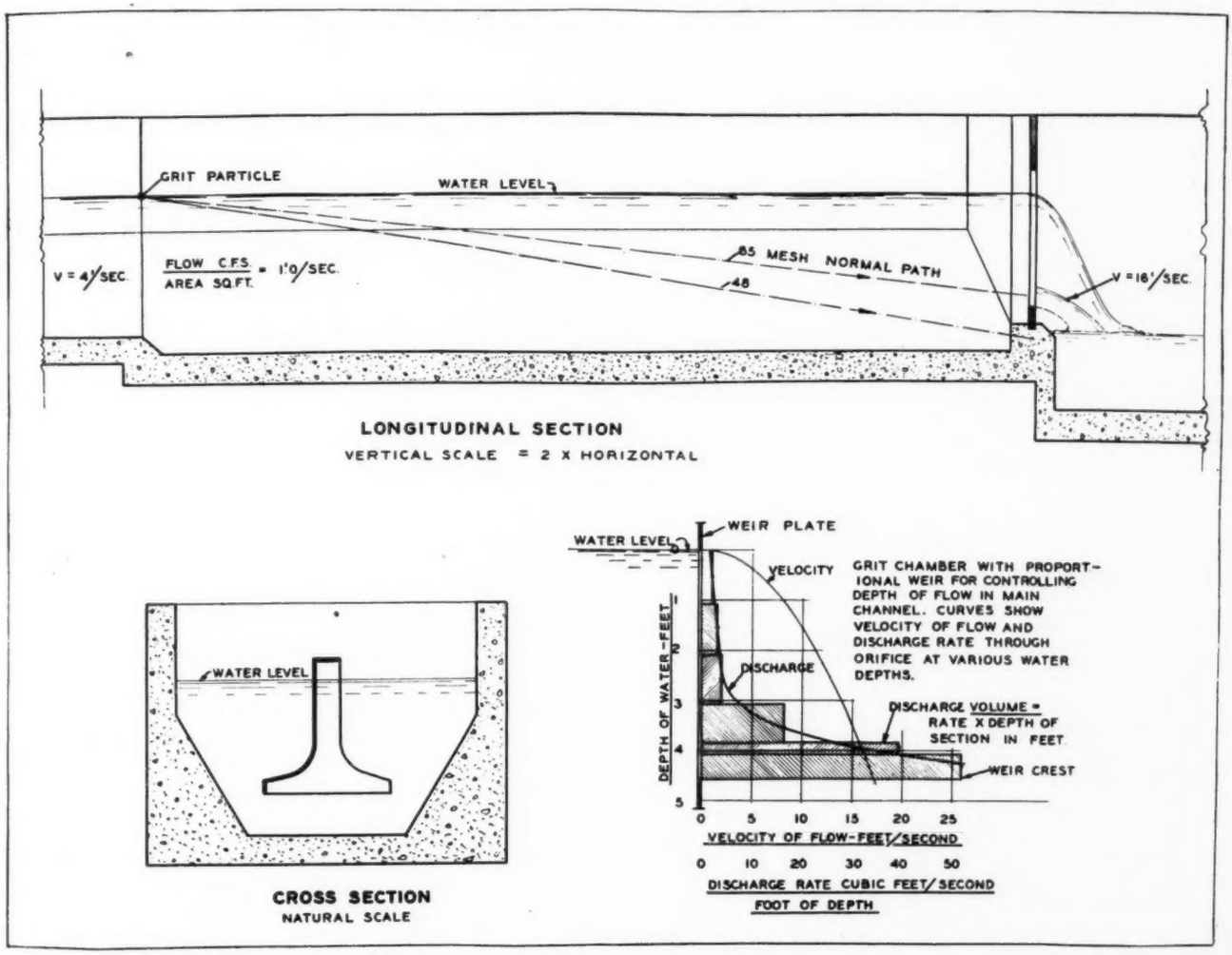

GRIT PARTICLE
WATER LEVEL
V = 4'/SEC.
FLOW C.F.S. / AREA SQ.FT. = 1'0/SEC.
65 MESH NORMAL PATH
48
V = 16'/SEC.
LONGITUDINAL SECTION
VERTICAL SCALE = 2 X HORIZONTAL
WATER LEVEL
WEIR PLATE
VELOCITY
DISCHARGE
GRIT CHAMBER WITH PROPORTIONAL WEIR FOR CONTROLLING DEPTH OF FLOW IN MAIN CHANNEL. CURVES SHOW VELOCITY OF FLOW AND DISCHARGE RATE THROUGH ORIFICE AT VARIOUS WATER DEPTHS.
DISCHARGE VOLUME = RATE X DEPTH OF SECTION IN FEET
WEIR CREST
DEPTH OF WATER-FEET
0 5 10 15 20 25
VELOCITY OF FLOW-FEET/SECOND
0 10 20 30 40 50
DISCHARGE RATE CUBIC FEET/SECOND FOOT OF DEPTH
WATER LEVEL
CROSS SECTION
NATURAL SCALE

Fig. 8—Recent Chamber Design Employing Proportional Weir.

Even though the design maintains a velocity of 1 ft./sec. satisfactorily, applying the settling path of 48 and 65 mesh grit reveals a lack of sufficient settling area for retention of 65 mesh grit and finer. How much 48 mesh grit will be retained is problematical.

and screen analyses made to determine the size and quantities of sand recovered at various distances from the inlet, as the result of varying velocities and depths of flow.

Thirty-five such tests were made, with nine samples of recovered sand from each test put through a screen analysis. Velocities ranged from .25 ft. per second to 1.15 ft. per second; weir settings from 6½ to 31 inches in height; and flow depths from 1 ft. to 3 ft., at 6-inch intervals. Such range was considered to cover the practical limits.

The results of these tests confirmed the assumptions, made earlier in this paper, concerning the most likely path of a sand particle of given size in a stream of moving water. Furthermore, and of equal importance, these tests confirmed our theory that surface area constitutes the all important consideration and yielded a wealth of data for the correct design of what, at the time, constituted an entirely new type of grit chamber.

Continuous Removal and Washing

We may now assume that on the basis of the foregoing, we can design a grit chamber which, if continuously cleaned, will remove, within the permissible velocities, all grit which might cause trouble in the plant. The usual practice, even in large sewage plants, is to use as few units as may be permissible.

Grit collecting units are designed for maximum flow conditions and almost universally to provide velocity not exceeding 1 ft. per second. During dry-weather flows there is a possibility that the velocity in the chamber may drop to as low as 0.2 ft. per second or even less, at which velocity quantities of organic materials will be deposited with the grit and removed by the collecting mechanisms. If no washing step is introduced before the accumulation is discharged by the collecting mechanism, the product will run high in organic and putrescible material, so that the mixture must be disposed of immediately to prevent nuisance. However, where grit is washed and well drained it can be used on roads and paths, on sand drying beds and for other purposes around the plant, without danger of creating a nuisance.

From the foregoing it is apparent that more than mere tank design should be considered. In addition to the all important size and shape relationships, consideration in modern design is being increasingly given to providing positive, continuous mechanical facilities for removing and washing the deposited grit, thereby lessening the need for maintaining exact velocities in grit separation units, and in precluding nuisance.

FIGURE 17

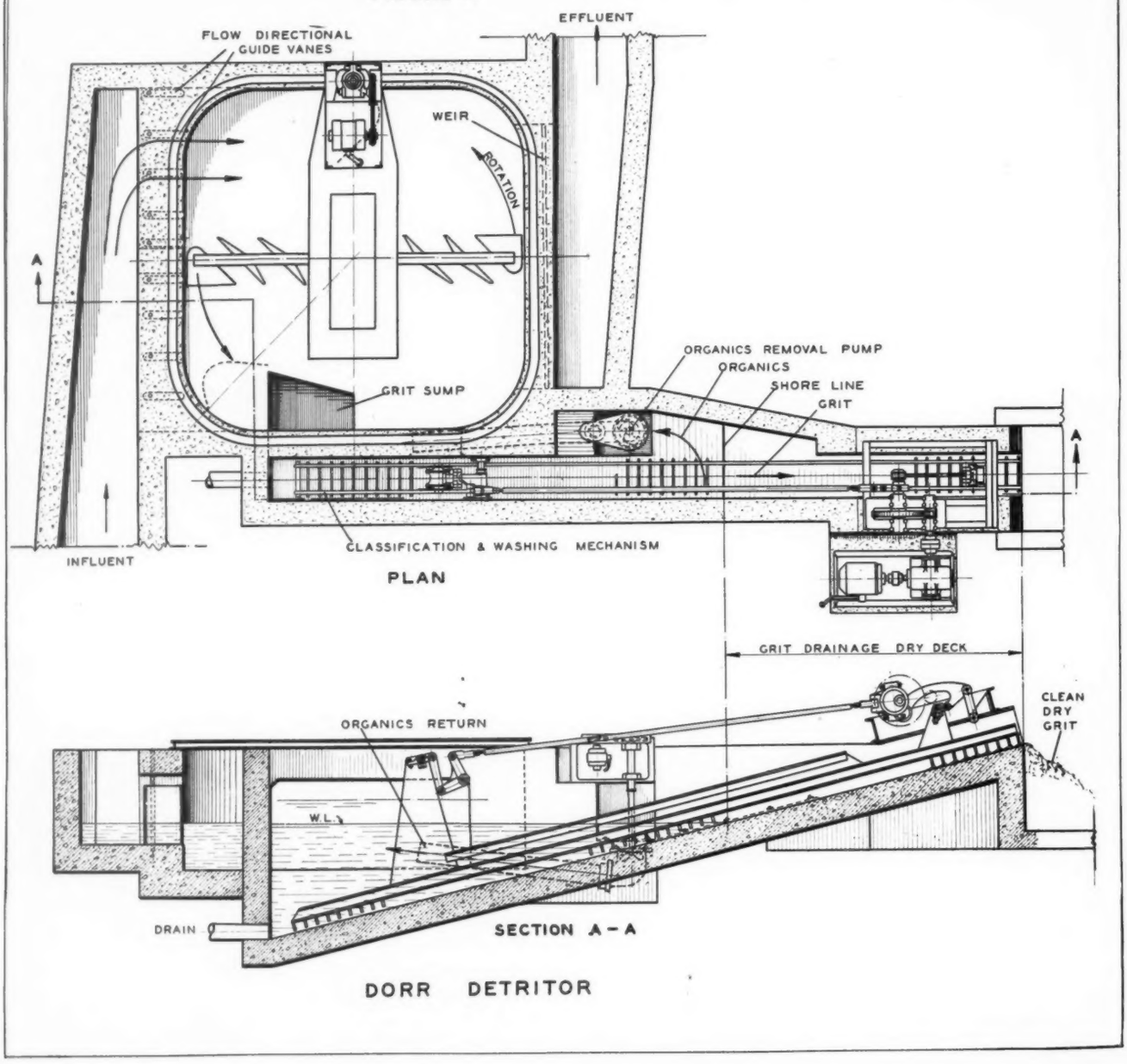


Fig. 9—The Dorr Detritor.

The Dorr Detritor

The Dorr Detritor (Fig. 9) was an outgrowth of our investigations. In reality the detritor is a process rather than a single mechanism. Because of the demonstrated importance of surface area, the tank has been made square in design and as shallow as permissible to safely deal with all flows. Influent enters through a series of guide vanes (on left) which may be adjusted to secure the most efficient distribution for the flows prevailing and those reached in later years. The sewage flows across the tank and over the low weir (right) to the effluent channel. All solids which settle on the floor of the tank are conveyed by a revolving and oscillating collecting mechanism to a grit sump.

The cleaning channel, which is adjacent to the collecting tank, is rectangular in plan and has a sloping bottom which extends from the grit sump to a point several feet above the "short line" at maximum highwater level. The cleaning mechanism has a reciprocating rake motion which conveys the settled material from the grit sump up the slope. (See Fig. 9.)

The reciprocating rakes serve to create turbulence which throws light organic materials into suspension as the rakes move the grit up the slope. As the material being raked approaches the "shore line" (water surface), a transverse flow of effluent, entering between the rakes and above the travelling layer of grit, furthers the transfer of the rejected organic material to one side while the grit is undergoing cleansing while it travels by back and fill motion gradually up the submerged slope.

The transverse flow is assisted by a specially designed nonclogging centrifugal type pump which takes away the dirty water and discharges it into the collecting tank, where it joins the flow toward the effluent weir.

The emerging washed grit is raked up the slope above water level. Here, all free water drains back and at the upper end of the slope the washed and drained grit falls into a suitable receiver.

The wash water employed consists solely of screened sewage.

The studies reported in this paper have extended over a period of some years. Preliminary field work was conducted at Philadelphia at the Frankford Grit Chambers in 1926 and 1927. In 1928 a more extensive program was carried out at Harrison, N. Y., simultaneously with our Westport flume tests. A vast amount of theory and practice had to be correlated and reconciled before there could be evolved an entirely new unit, based upon a

Fig. 10—Detritors at Baltimore, Md.
The 3 Units Have a Design Capacity of 100 M.G.D. Each; at a Power Consumption of 4½ H.P. Each.

OPERATING DATA—DETRITOR INSTALLATIONS—WASHED GRIT

			DETRITOR		GRIT (Cubic Yards)			WASHED GRIT									
LOCATION	M.G.D. Flow Aver.	M.G.D. Max. Storm	Feet Square	Max. Water Depth	Av. Per Day	Max. Per Day	Max. Per M.G.	10	20	35	48	65	100	150	% Putres. (Dry Basis)	% Volatiles in Putres.	Odor
Austin, Tex.	2.0	4.5	18'	3'6"	0.12			9.3	26.1	59.8	76.3	91.0	97.6	99.2	0.85	29.0	None
Baltimore, Md. ..	81.52	243	50'	6'4.25"	16.2	45	0.54	6.7	17.7	42.6	66.1	88.0	97.4	99.5	3.1	56.0	Slight
Barrington, Ill. ..			10'	1'3"													
Battle Creek, Mich.	5.8	8.6	26'	2'6"	4	54	6.30	44.2	81.9	93.5	95.5	97.4	98.8	99.4	2.1	54.1	None
Beacon, N. Y.....	0.635	0.97	10'	1'5"	.074	.67	0.69	20.7	34.0	54.5	69.8	87.7	95.0	98.0	3.3	61.8	Slight
Berea, Ohio	0.400	2.00	10'	1'9.5"	1	1.5	0.75	58.5	83.1	93.0	95.2	97.0	97.3	97.5	4.6	50.4	Musty
Birmingham, Ala.	8.71	16.0	22'	2'9"	0.24	0.48	0.03	31.4	52.9	79.6	89.6	95.3	97.5	98.6	3.5	46.4	None
Cedar Rapids, Ia..			22'	2'6"				2.1	5.7	15.0	26.0	48.9	71.2	81.5			
Cleveland, Ohio (East)	80.0	92.0	40'	3'10.25"	1.0		20.0	13.5	26.4	63.3	89.5	94.0	97.6	98.0	1.4	48.8	None
Cleveland, Ohio (West)	15.16	23-25	35'	2'6"	.77			14.7	23.7	47.7	70.6	90.0	97.6	99.5	0.95	19.0	None
Colo. Springs, Colo.	4.67		18'	2'0"				23.3	52.2	89.0	97.6	99.3	99.6	99.8	0.4	49.5	None
DePere, Wis.	0.476	2.285	10'	1'6"	150 lbs.	1368 lbs.	0.20	20.9	39.0	57.7	69.0	81.5	91.0	95.0	7.3	24.0	Musty
Dixon, Ill.	0.72	2.00	10'	1'3.75"				20.9	36.7	81.2	92.7	95.5	95.6	96.0	5.5	67.1	Foul
Duluth, Minn.			26'	2'9"				11.7	34.5	65.5	81.2	92.1	97.4	99.4	1.72	37.1	None
Elmhurst, Ill.	1.5	2.5	14'	1'9"				13.6	35.5	67.6	84.3	94.6	98.5	99.0	1.5	42.5	Musty
Fargo, N. D.....	2.0		14'	2'0"	0.15			32.1	54.7	74.4	82.0	89.2	94.7	98.4	8.7	62.9	None
Farrel, Pa.			10'	1'6"													
Findlay, Ohio	2.0	10.0	20'	2'0"	0.09	0.27	0.03	32.8	58.1	79.1	88.8	95.5	98.1	99.2	2.6	69.2	Slight
Ft. Dodge, Ia.....	1.8	3.0	12'	1'4.5"	0.22	0.37	0.12	51.7	74.8	84.4	86.2	88.6	93.8	98.7	2.4	85.7	None
Green Bay, Wis...	5.0	20.0	26'	3'0"	1.30	5.60	0.28	3.7	9.1	19.8	29.6	51.7	78.2	96.1	1.23	43.5	None
Greensboro, N. C..	5.2	15.0	14'	2'2"	0.12												
Houston, Tex.			26'	2'8.5"													
Jeanette, Pa.	0.9	1.5	10'	1'6"	0.19	0.45	0.30	55.5	84.6	97.3	98.3	98.4	98.6	98.7	2.30	71.5	None
Klamath Falls, Ore.	2.0	4.0	12'	2'6"	0.19			32.8	65.5	80.1	83.1	85.4	87.5	90.5	12.5	79.2	Slight
Kokomo, Ind.	2.82	4.35	15'	1'6"	0.15	1.60	0.37	13.0	24.8	50.2	68.0	87.1	95.9	99.0	0.8	23.0	None
La Crosse, Wis..	5.20	12.0	26'	2'6"	0.56	2.50	0.21	10.8	24.4	40.8	62.4	86.4	97.5	99.2	0.8	70.6	None
Lansdale, Pa.			10'	2'8"													
Muskegon, Mich..,	4.0	10.0	20'	1'7"	0.22	3.00	0.30	9.4	14.9	38.0	69.1	92.2	98.8	99.0	0.6	55.5	None
Norwalk, Ohio ..			10'	1'9"													
Phoenix, Ariz. ..	13.0	20.0	60'	4'0"	0.28			17.0	42.7	80.7	91.2	96.0	97.5	98.1	2.2	40.3	Musty
Pottstown, Pa. .	1.0	5.0	11'	2'4"	None	0.26	0.05	27.0	54.4	81.6	90.4	95.5	97.8	98.7	3.25	50.0	None
Rockford, Ill. . ..	9.82	17.25	24'	3'1.25"	2.4	10.2	0.59	22.4	40.5	73.5	91.1	97.6	99.0	99.5	0.9	57.8	Musty
Seattle, Wash. ...			15'	2'5.5"													
Sioux Falls, S. D..	2.30	9.00	14'	2'6"	1.4	5.0	0.55	5.0	18.4	62.9	84.4	95.2	98.5	99.3	0.37	63.0	None
Souderton, Pa. ...	0.23	0.80	10'	1'6.75"	None	1.20	0.67	56.5	76.4	94.2	97.5	98.5	99.0	99.2	1.23	19.0	None
So. Milwaukee, Wis.			10'	2'6"													
Springfield, O. ...	14.0	28.0	28'	2'9"	1.1	6.0	0.24	26.0	48.0	73.9	86.0	95.8	98.4	99.0	1.6	40.0	Slight
Stockton, Colo. ...			15'	2'5.5"													
Toledo, Ohio	30.0	100.0	40'	5'0"				65.2	92.0	95.7	98.4	98.5	98.6	99.0	1.35	60.0	None
Va. B'ch, Va.....	0.35	2.0	10'	2'0"	0.03	0.56	0.28	16.5	25.9	40.6	65.0	89.0	97.6	99.0	6.0	64.3	Musty
Uniontown, Pa. ..								22.7	36.9	56.4	60.5	80.0	92.0	97.5	1.8	23.5	None

new concept of optimum design factors, such as is the Detritor. Today there are 110 of these machines in operation here and abroad. Operating data from 41 different installations are given in the accompanying table.

Conclusions

Based on experience, and studies cited in this paper, we believe that a satisfactory grit chamber should be designed on the following basis:

One—Capacity should be in direct proportion to the area, regardless of the relations of width, depth, length and velocity.

Two—Grit particles should be pictured as settling at the same velocity, with respect to the moving stream of sewage, as in a quiescent pool.

Three—The chamber should be designed in accordance with the specific characteristics of the grit to be removed, the aim being to remove all grit particles coarser than 65 mesh. And, in certain cases, all settleable non-organic particles coarser than 100 mesh.

Four—The final washed grit should be generally free of putrescible matters and in no event should it contain in excess of 3 per cent by weight of such.

Five—Grit should be drained completely of visible free-water before its discharge from the washing and draining units.

Six—The chamber should be so designed hydraulically as to operate readily over the full range between maximum and minimum flows, without appreciable loss of head.

Seven—The collecting and washing mechanisms should at all times deliver a clean grit within the limits specified in *Three* and *Four* above, without any adjustments being required for variations in rates of sewage flow or grit deposition.

Eight—The entire unit should be so designed structurally and mechanically as to preclude any possibility of septic action, odors, or unsightliness.

All of these desirable features may be readily obtained if the specifications on which bidding is solicited are drawn on a uniform basis that require all purveyors of competitive types of equipment to give the same guarantee in respect to performance and delivery of grit that measures up to a uniform established standard in respect to content of water and putrescibles.

GRIT CHAMBERS*

Design and Operating Practices of Yesterday and Today

By M. B. TARK and J. J. GILBERT
Engineers
Link-Belt Company, Philadelphia, Penna.

THE ideal grit chamber should remove all sizes of grit that may cause trouble in the other units of the plant. The putrescible matter in the grit should be very low. Due to the characteristics of grit, the latter attainment is difficult in many plants, as the separation of the grit from the organic material depends upon specific gravity and the shape of the particles. Very often the grit particles are covered with grease or adhere to organic material. Grit has been very aptly described as "sand on roller bearings."

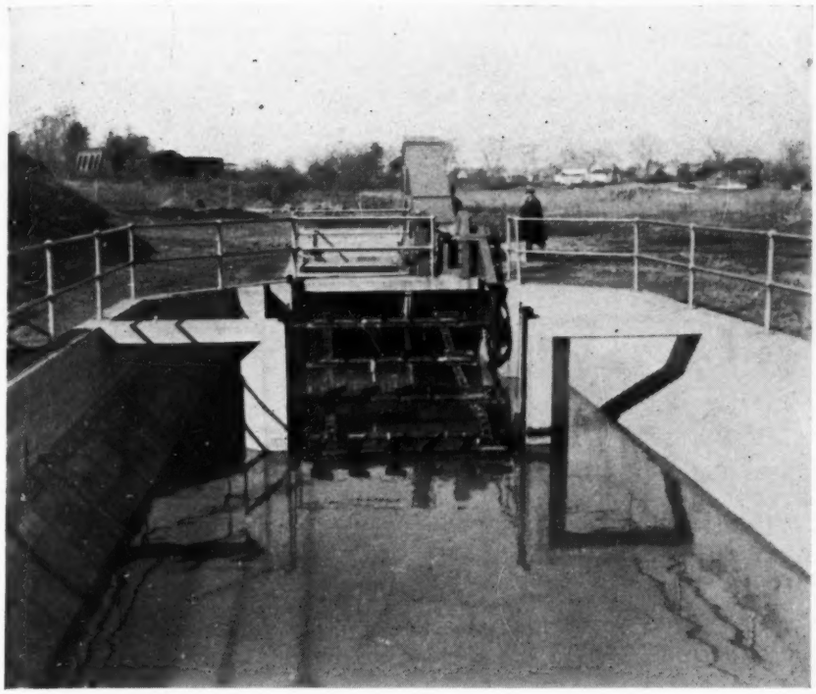
Many methods have been tried to separate the organic material from grit. One of the most common is the maintenance of uniform optimum velocities through the grit chamber. Such selective velocities are supposed to permit the grit to settle, while the lighter organic materials pass through the chamber to be treated in the other units of the plant. A velocity of 1 ft./sec. was almost universally employed to accomplish this result and a number of grit chambers were designed to provide this velocity. To maintain a uniform velocity at all times, chambers with "V" shaped cross section were designed to take care of variations in flow. In other cases rectangular chambers were installed with gates or weirs at the effluent end to maintain this velocity. Very shortly it was found that the large volume of organic material deposited in the grit made it a very objectionable material to

*This paper was one of a group of three on the same topic presented November 29, 1939, before the Sanitation Group of the Am. Soc. of Mechanical Engineers in New York City.

LINK-BELT COMPANY

Month 1937	Flow M.G.D.	Velocity Feet per Sec.	Grit Removed: Total Cu. Ft.	Cu. Ft. per M.G. Sewage	Per Cent Moisture: Fresh	Per Cent Moisture: Washed	Per Cent Putrescible Matter: Fresh	Per Cent Putrescible Matter: Washed	Per Cent Putrescible Matter: % Red.	Organic Nit. Mg. per Gram Dry Solids: Fresh	Organic Nit. Mg. per Gram Dry Solids: Washed	Organic Nit. Mg. per Gram Dry Solids: % Red.
January	60.0	1.31	2565	0.30	40.7	34.6	3.35	2.36	29.4	1.67	1.00	40.5
February	59.7	1.31	2025	0.29	32.6	21.9	2.05	1.33	35.1	1.07	0.76	26.5
March	59.1	1.29	675	0.09	31.6	29.4	2.36	1.87	19.1	1.23	0.94	27.1
April	59.3	1.30	4590	0.59	45.2	36.2	3.57	1.70	42.7	1.57	0.86	41.0
May	59.1	1.26	6885	0.83	49.8	24.2	5.45	1.96	63.8	2.51	0.77	41.8
June	59.2	1.27	7290	0.91	37.2	22.2	1.81	1.03	42.2	1.23	0.60	51.6
July	60.0	1.29	8640	0.96	33.9	22.9	2.58	1.87	21.2	1.45	0.83	32.8
August	60.8	1.32	8370	0.85	42.9	33.5	2.96	2.02	32.8	1.49	0.84	42.0
September	60.9	1.33	3591	0.41	44.9	27.7	2.65	1.30	41.9	1.26	0.73	40.8
October	60.7	1.32	4617	0.49	40.6	30.4	3.80	1.41	59.0	1.61	0.50	66.8
November	49.7	1.09	3591	0.46	46.2	41.5	5.17	4.50	14.1	2.71	1.88	31.9
December	47.2	1.03	3105	0.39	60.5	31.9	4.06	1.92	68.3	2.91	0.96	60.5
Total Average	58.0	1.26	55,944	0.56	41.7	28.9	3.33	1.85	44.4	1.72	0.85	50.5
1936 Total Average	41.2	1.20	67,594	0.93	37.4	30.9	2.30	1.45	37.0	1.44	0.79	45.2

Grit Removal and Washing Results at Chicago's West-Side Plant



The Grit Chamber of the Rahway Valley (N.J.) Plant "Straightline" Collector and Dewatering Screw Conveyor.

handle. In consequence, other means providing a better separation have been devised and employed. Amongst these were the following schemes.

Roughing tanks, with about 10 minutes' detention, were installed ahead of settling tanks and a constant volume of the settled material was pumped continuously through the much smaller grit chambers, providing a uniform velocity. Several plants of this type were built, the principal ones are at Akron and Dayton, Ohio, and the West Side Plant of Chicago. These plants did not work out as expected, because as much as 60% of organic matter was contained in the discharge from the grit chambers handling the detritus tank deposits.

Another method was that of washing the grit after its removal from the grit chamber, and this is now accepted as the most practical and effective process. One of the first plants designed to use this method was at Philadelphia. The original design provided a machine, somewhat similar to a dredge mounted on trucks, which was to remove and discharge the settled material to a trough. The trough was to discharge the grit into a tank, in which it was to be thoroughly washed and the organic material floated off by wash water applied at the bottom. The price on the machine for the removal of the grit exceeded the money available and it was never installed. The grit is now removed by shoveling from the chamber to a water ejector which discharges to the wash tank. A very clean grit is obtained by this method so that the wash tank is used only for storage. A similar method on a smaller scale is used at the Boonton, N. J., plant and probably at a good many others.

Grit Washing Developed

About 12 years ago a demand arose for the removal and washing of grit by mechanical means. To meet this demand at least two manufacturers designed machines for such purpose, the earliest installations being that at Chester, Penna., and another at Harrison, N. Y., which followed shortly.

The mechanism in grit chambers has two objects. First, to operate at such a speed to permit the settling out of the grit but to keep most of the organic material in suspension so that it will be swept out of the grit chamber, while the higher gravity remains behind. Second, to gather together and discharge the collected grit above the water line of the chamber.

If the collecting mechanism does not effectively stir the grit deposited in the chamber, but merely serves to collect all of the grit and organic material that settles in the chamber and deliver it to the washer, the load on the latter unit will be unduly heavy. As a result the performance of the washer is apt to be unsatisfactory unless this unit is designed for such extra duty and a comparatively large volume of wash water is used. At the West Side Plant of the Sanitary District of Chicago, flight conveyors were installed to remove the grit from two of the chambers, this grit was carried to a screw washer, followed by a dewatering screw, and thereupon discharged to railroad cars. A clean grit was obtained by this rather complicated method. The installation was experimental and was mostly made up from material at hand. The washer was recently removed.

Each drag conveyor of the Chicago unit consists of a single strand of combination chain with 2x6 wood flights spaced approximately every 2 ft. 6 in. Each flight is equipped with renewable wearing shoes. The original installation had the flights spaced every 5 feet, but considerable breakage of flights occurred during the time of storms. Due to the heavy load of grit, for the past year and one-half the conveyors have been operating with the flights spaced every 2 ft. 6 in. approximately. The speed of the conveyor is approximately. 2.4 ft. per minute and the inclined portion of the conveyor is 30° to the horizontal. When the washer was in service, the grit was discharged on a belt conveyor running at right angle to the two grit chamber drag scrapers. From the washer it was discharged onto a distributing belt conveyor traveling above flat cars. Now that the washer has been removed, the grit travels direct from the drag conveyors in the grit chambers to the cars without any washing.

When washing grit, raw sewage was used to do the washing and a pump having a capacity of 90 gallons per minute was operated continually, pumping the influent from the grit chamber direct to the washer. The grit was dumped directly into the washer and when they started up, very poor results were obtained. To get better results, both the grit and the wash water were added into a spiral trough above the water level in the screw washer and allowed to flow spirally down into the screw compartment. This turbulent action improved the washing of the grit considerably and the accompanying results reveal that a fairly clean grit was obtained.

It was also found that 90 gallons per minute of wash water was not sufficient at the time of storms and a new pump, having a capacity of 200 gallons a minute, had to be installed. This pump runs continuously regardless of the amount of grit going to the grit washer. During storms the volume of grit is about twenty times the average.

An Ingenious Grit Chamber

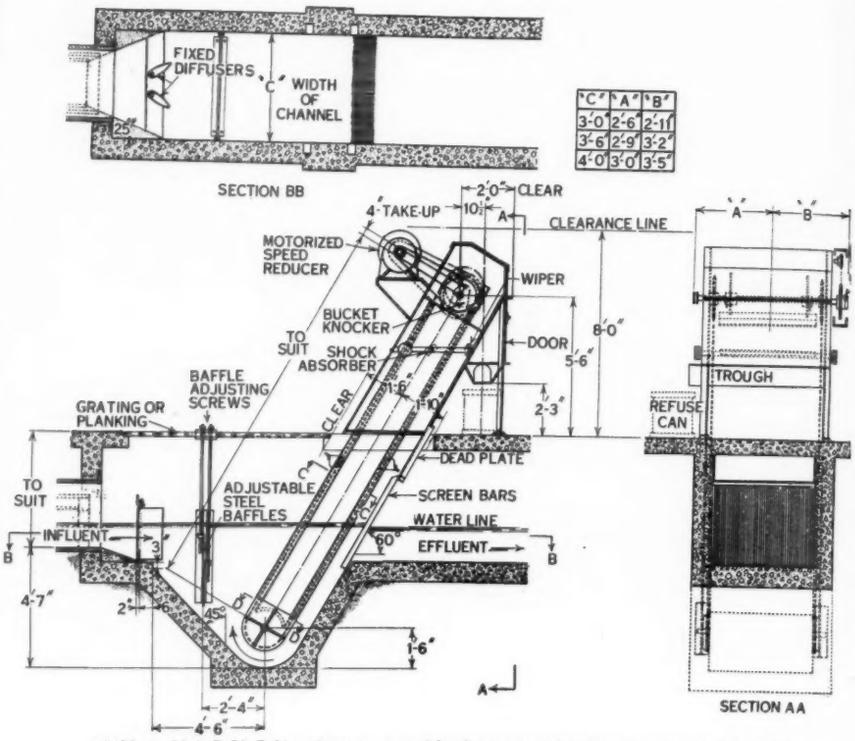
A rather ingenious grit chamber was designed by Blunk, Chief Engineer of the Emscher Genossenchaft. It consists of a number of concentric compartments with overflow weirs which are set at different levels so that more and more of these compartments come into use as the flow increases. The grit and some organic matter settle in the hopper bottom and the grit is thoroughly washed by means of water and air jets before it is discharged by means of an air lift. A good grit is obtained by this method even though the sewage is heavily charged with fine organic solids.

The "Tritor Screen"

The "Tritor Screen" is a machine manufactured by the Link-Belt Co. It combines the functions of a mechanically cleaned bar-screen and grit chamber. (See illustration.) This screen is especially recommended for small plants where it is not economically feasible to install too many separate mechanical units. Adjustable baffles at the influent maintain a velocity of approximately one foot per second at the bottom of the sump. The heavier grit settles to the bottom, while the organic matter is kept in suspension. The floating material is collected on the bar rack, while the grit is removed by means of buckets. Automatic intermittent operation is provided by means of a time clock. There are over 60 of these machines now in use.

AMOUNT OF SEWAGE TREATED DAILY				REMOVAL OF GRIT	
INDICATED BY VENTURI METERS			TEMP. SEWAGE °FAHR.	GRIT	
MONTH	RAINFALL TOTAL	M.G.D.		CU.FT.	PER M.G.
JANUARY	3.16	28.51	52.6	259	9.10
FEBRUARY	1.93	28.94	51.0	227	7.85
MARCH	2.13	27.34	53.0	225	8.24
APRIL	2.52	27.58	56.0	228	8.28
MAY	2.99	22.01	60.0	139	6.32
JUNE	4.95	26.94	64.0	161	5.98
JULY	6.95	31.50	66.0	160	5.08
AUGUST	2.18	24.69	68.0	100	4.05
SEPTEMBER	7.81	26.59	68.0	161	6.05
OCTOBER	1.44	21.06	65.0	117	5.55
NOVEMBER	1.71	20.59	62.0	150	7.28
DECEMBER	2.42	29.55	56.0	134	4.54
YEARLY AVERAGE	TOTAL 40.19	26.28	60.1	172	6.54

Operating Data—Elizabeth, N. J.
Note the effect of increased velocity (May forward) in decreasing volume of organics removed as "grit."



21415 — Link-Belt Tritor Screen, a combined screen and grit chamber, April, 1936.

The Link-Belt "Tritor Screen"
A Combination Unit—Screen and Grit Chamber.

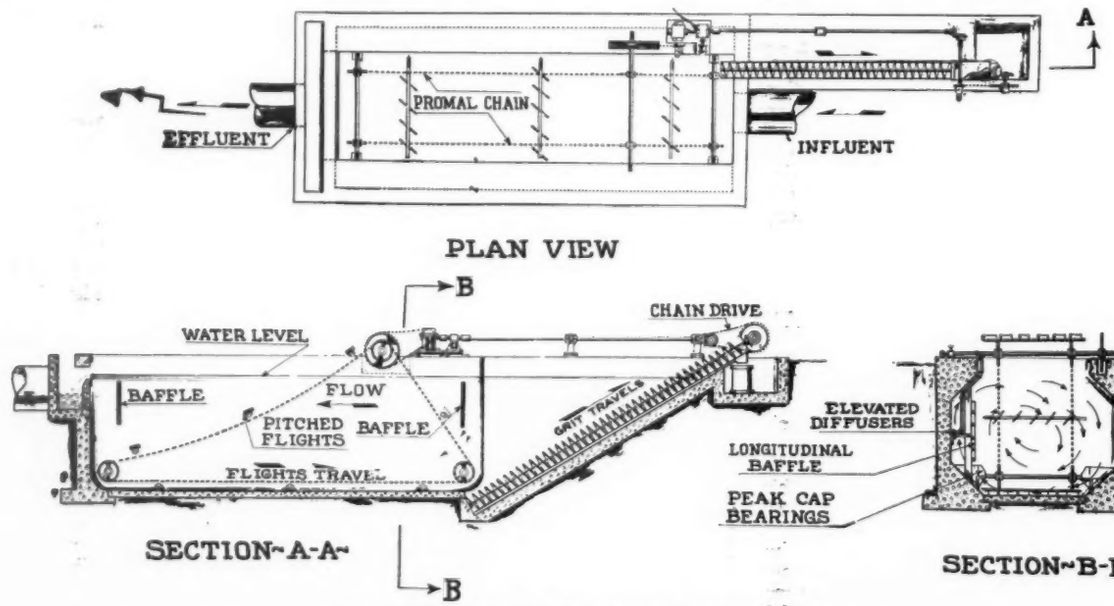
The "Straightline" Grit Remover

The Link-Belt "Straightline" Grit Chamber consists of a collector with pitched flights that turn the settled material over and over while moving it to one side or the center of the chamber. Here the grit is picked up by the screw of the washing mechanism, which elevates the grit while it is being washed. The duty on the collectors and wear is very much greater than that of similar collectors in settling tanks Such necessitates use of a different type of chain with larger wearing surfaces, and the tracks and other sliding surfaces are provided with abrasion resisting steel.

The velocity of flow through such chambers must be maintained at 0.5 ft./sec. in order that the organic material liberated by the screw washer, and kept in suspension by the action of the flights, may be continuously washed out. Results obtained by maintaining the effective 0.5 ft./sec. velocity at the Joint Meeting Plant located in Elizabeth, N. J., are revealed in the accompanying table. During the first four months, two grit chambers were kept in service, whereas in the following months only one chamber was employed. The decrease in the recorded volume of grit removed was entirely due to the more efficient flushing out of heavy organic materials when operating the chambers at the higher velocities.

The great variation in the removal of grit from day to day at many plants is well illustrated by the records at the Peoria, Ill., plant, where the volume of grit removed varies from 2 cubic feet to 560 cubic feet in one day, following a 7 inch rainfall. At Peoria, although the average chamber velocity was only 0.3 ft./sec.; the cleansed grit contained but 9.8 to 17.9% velocities and only 0.35 to 0.53% putrescibles.

Where it is necessary to use a separate grit washer, a certain minimum volume of wash water is required. This wash water



Spiral-Flow Grit Chamber Employing Compressed Air
Equipped with "Straightline" Collector and Elevating Screw Which Cleanses and Dewaters Grit.

may be either clarified sewage or mixtures of clarified sewage and clean water. In such washers the arrangement of the influent and effluent channels is of the greatest importance and much of the success of the operation depends upon the arrangement of the water jets employed to separate the organic material from the grit and float it to the effluent channels.

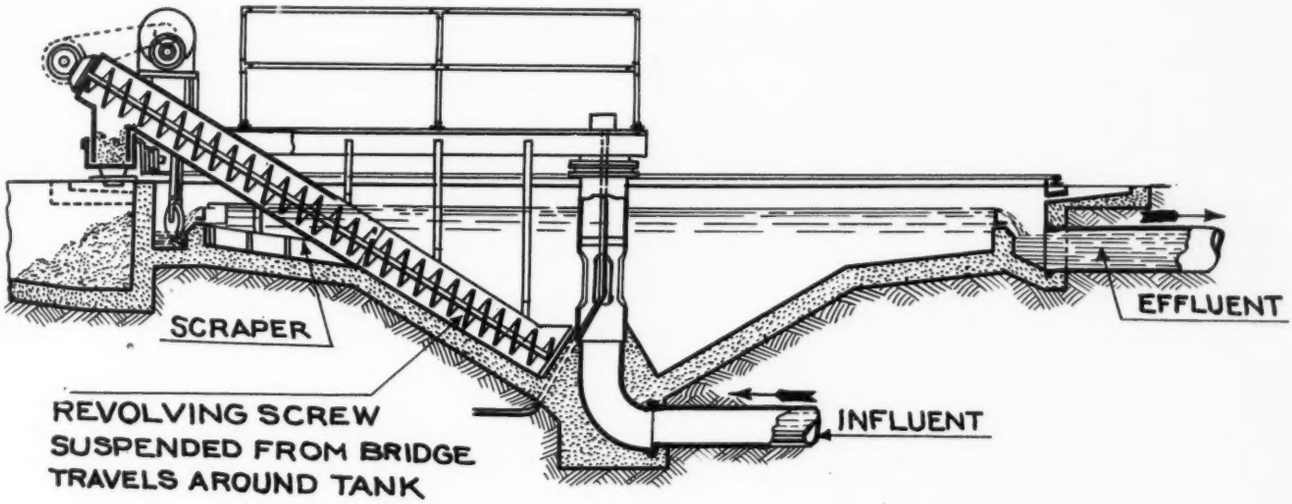
Spiral Flow Type of Chamber

The Link-Belt Flow Grit Chamber makes use of the same mechanical equipment as the "Straightline" chamber. The chamber, however, is constructed so as to permit introduction of compressed air in a manner to create a spiral flow in the chamber, (see illustration). The purpose of the air is that of creating a uniform velocity regardless of fluctuation in sewage flows. The end sought is that of insuring that organic matters are maintained in suspension for effective sweeping out by even the minor sewage flows. Thus, a much cleaner grit and less volume load is imposed on flights and the washing mechanism. The scheme is very effective.

The New "Circuline" Grit Chamber

The Link-Belt "Circuline" Grit Chamber (here illustrated) is a new development and has many desirable features not found in any other type of grit separatory unit. The sewage and grit enters at the center at a very high velocity, which tends to sweep the organic materials toward the circumferential weir. A rotating screw maintains uniform agitation in all parts of the tank, separates the grit from the organic material and throws the organic material upward and toward the outlet. A travelling scraper removes any materials that may strand in the effluent weir.

Such a machine will be able to handle very heavy deposits of grit on account of its ruggedness. Another decided advantage is its simplicity, flexibility, and low head loss in handling the large flows.



CIRCULINE GRITCHAMBER

The New "Circuline" Grit-Chamber
Operates on the Radial Flow Principle. Features Rugged Design and Revolving Screw Mechanism.

KEEPING LIME SOLUTION LINES CLEAN

To retard building up of incrustation and depoits, which choke pipe lines conveying lime suspension, the following has been found very helpful at the Richmond, Va., Filter Plant. A program clock at 4 hour intervals opens and closes a flushing valve connected into the line at the inlet end. The line is thereby automatically scoured free of the loosely deposited carbonate and hydrate 6 times daily.

If a scale gradually builds up which the Richmond scheme of water scour will not remove, chlorine water from a chlorinator can be run through for the required period to dissolve or loosen the scale. Chlorine water applied to lime carbonate reacts to produce hypochlorous acid, carbon dioxide and calcium chloride as indicated by the reaction.

$$CaCO_3 + H_2O + 4\,Cl = 2\,HO\,Cl + CaCl_2 + CO_2$$

Pouring chlorine water slowly through a column of ground limestone or marble will demonstrate the reaction and is a well known method of preparing hypochlorous acid. The solution resulting, because of the weakness of the hypochlorous acid produced, has a pH of 8.0 to 8.2.

After the carbonate is all converted, chlorine water will naturally attack metallic solution lines. Lines of rubber hose with jointing made by butting hose ends together *inside* of a short sleeve of larger size hose, or a short section of pipe, provides a very satisfactory all purpose chemical feed line.

HOW TO BEND PIPES

TO bend steel pipes, fill with dry sand and plug the ends. Heat to a red heat in the localities to be bent and then bend. *Be sure that the sand is dry.* Where bends are slight, it is often unnecessary to use sand. The object of sand is simply to keep the sides of the pipe from collapsing, or to prevent reduction of flow area. If wet sand is used, and if the ends are plugged, the pipe may burst when heated, due to the steam pressure generated.

For the smaller pipes instead of sand resin is good. There is, however, a "right way" and possibly several wrong ways to use resin. An example of a wrong way was recently brought to my attention where the mechanic filled the pipe with resin, plugged the ends, and heated the pipe at the place where he wanted to bend it. He watched for a "red heat" just as he would had he filled the pipe with sand. The result was a violent explosion.

To use resin correctly, pour it into the pipe molten and allow it to cool and harden. As soon as the resin is hard, bend the pipe cold. Don't heat it. Then after the pipe is bent, heat the pipe all over sufficiently to melt and remove the resin.

Equal results may be secured by using lead instead of resin. I have been told that on cold days water has been used also.

Many excellent mechanical devices are on the market for bending pipe. To bend large, stiff pipe slightly (and inexpensively), there is nothing handier or more efficient, in my judgment, than a hydraulic pipe bender driven by a hand pump.

GRIT COLLECTION AND WASHING*

With Particular Reference to Jigging as an Advanced Method

By R. D. NICHOLS
Engineer
The Jeffrey Manufacturing Co., Columbus, Ohio

THE removal of grit from sewage, prior to sedimentation of the organic solids in clarifying units, has been practiced for many years. The efficient and economical practice of this important phase of sewage treatment requires several steps which, if properly followed, will produce the results desired. These steps are:

(1) First, the larger suspended solids should be removed from the crude sewage by effective screening.

(2) Thereafter, the sewage is passed through a channel or chamber, designed to give only a brief period of detention and to provide velocity of flow which will permit the gritty materials to subside while all but a fraction of the organic materials are swept through.

(3) The settled materials must be removed from the chamber, preferably at frequent intervals by continuous type mechanical scrapers or collectors.

(4) Then, unless an efficient means of separating the residual organic matters from the collected grit, and return of such to the sewage, is not employed, disposal of the grit mass constitutes an added problem and an extra expense.

During the past few years new plant designs have incorporated mechanical units for screening out coarse solids, for removing deposited grit from the settling chamber, for the washing of such deposits to free the grit of organic solids, and return of the dirty wash-water to the sewage for subsequent treatment.

This paper will now briefly enumerate some of the elementary rules of design which have been in vogue in recent years. This, in order that these rules may be compared with observations of the writer and others with whom the problems have been discussed.

Detention Periods

In designing grit chambers, engineers have generally considered one-half minute as the minimum detention period permissible, based on maximum flow. Approximately one and one-half minutes' detention has been the maximum, except under most unusual conditions.

Only recently have control devices been widely used to maintain a fairly constant velocity throughout variations of flow.

The prevailing factor in determining detention period is the maximum sewage level and the closeness of adherence to the rule of thumb law of 10 feet of length for each foot of depth. Generally in the design of long narrow channels, for a maximum sewage depth of from 3 to 4 feet, the rule is followed closely. In some larger plants there has been some deviation in this rule, reducing length and detention period.

Velocity of Flow

A velocity of flow through grit chambers or channels of one foot per second has been considered adequately low for the settling of inorganic solids. This does not mean, however, that some organic solids will not settle also. Velocities lower than one foot per second usually results in an excessive amount of organic solids appearing in the settled grit.

Prior to the use of facilities for automatically controlling flow velocity, operators attempted to obtain clean grit by controlling the depth of sewage flow in the channels, thereby maintaining velocity within a relatively narrow range.

The related rules are based upon the free settling velocities of solids and the assumption that fine grit is in suspension in the upper strata of flow as the sewage enters the separatory unit.

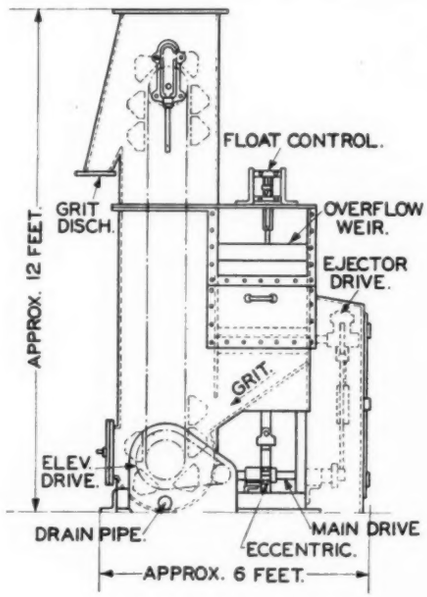
The writer questions whether inorganic solids of any consequence are actually found in suspension in relatively low velocity of sewer flow (under 3 ft. per second), unless there is some artificial means to create turbulence. Grit in sewers, influent channels or screen chambers, designed so as to preclude sudden changes in velocity, has already had an opportunity to settle. It may be termed a "lazy animal" and will be found on or near the bottom where it may be collected. Therefore, in designing grit channels, the velocity should be reduced in a manner that will provide little chance of creating disturbance or turbulence. Organic solids that settle out with grit in chambers of very low velocity are quite difficult to separate unless some method of classifying is employed in the washing operation.

*This paper was one of a group of three, presented before the Sanitation Group of the Am. Soc. of Mechanical Engrs. in New York City, on the same topic. All three are presented in this issue by permission of the Society.—Ed.

Relationship of Length and Depth

The writer has not reviewed all the literature on the subject, but Bloodgood (Sewage Works Journal, May 1939) refers to a reduction in the length of grit channels without seriously affecting the results. The channels at Indianapolis were 55 feet long and had a constant velocity weir at the effluent end, designed to maintain a velocity of one foot per second. The detention period, of course, was approximately one minute.

The water depth at maximum flow was approximately 10 feet; therefore the ratio of length to depth about 5.5 to 1. These channels were reduced from 55 feet to 20 feet in length by moving the foot shaft of the collector mechanism and the constant velocity weir. With the new arrangement the detention period is only



The "Jigrit"
Showing General Dimensions and Design.

20 seconds, and the relation of length to depth is now 2 to 1. In the Indianapolis plant the main sewer, and influent channels are in substantially a straight line of flow, the grit has already settled out and, in consequence "drifts" into the grit chamber.

Bromage (Seweage Works Journal, May 1939) concurs in this opinion. He states: "Immediately beyond the screens are two curved weirs and a horizontal slab which diverts the lower strata of sewage, which contains the road grit, into two detritus separating wells, while permitting the upper strata to pass straight on."

Reference to the Bromage article does not mean that the writer believes grit channel designs should provide a by-pass for the upper portion of sewer flow. However, it does substantiate the opinion that grit is carried in the lower strata of a free straight-line flowing sewage stream and, in consequence, can be removed in short channels as satisfactorily as in long ones, especially if velocity control devices are employed.

The control of velocity, the absence of undue turbulence, and the utilization of collectors that create relatively quiet pools between the conveying elements should be found to permit the use

of shorter channels and reduce capital expenditures as well as cost of maintenance.

Grit Removal Mechanisms

Grit removal mechanisms are of two distinct types—those that merely remove grit and those that combine washing with removal.

There are scraper conveyor mechanisms that move grit along the bottom and deliver it to an inclined screw for washing. The removal mechanisms have conveyor elements interspersed with plows that move solids back and forth, thus assisting the washing operation.

There are scraper conveyors that traverse the bottom of channels and continue upon an inclined deck to wash the grit at the point of emergence from the liquid and further to dewater it. Some of these also have plows for abrading the settled grit by moving it back and forth.

There are square tanks that have rotating collector mechanisms that deliver the collected grit to a washing compartment, usually positioned alongside the tank. An oscillating rake type mechanism washes and elevates the grit, dewatering it after leaving the sewage.

There are V-bucket conveyors longitudinally traversing the channels, to collect the grit and elevate it. Some of these have plows interspersed between the buckets to effect a washing. There are V-bucket conveyors also used in combination with scraper type conveyors.

Some designs have separate grit washers located outside the flow of sewage. Screw conveyors have been used in separate compartments. The oscillating rake mechanism has also been used in separate compartments.

The Newest Grit Washing Unit

The most recent development in method of grit washing and apparatus is a combination of the V-bucket collector and elevator which delivers the grit to a machine called the "JIGRIT."

The "Jigrit" method not only "scrubs" the solids to free the adhering organic matter but classifies these solids and finally separates them, sending the organics over the weir in the wash water which is returned to the sewage stream. The washed grit is dewatered and delivered to containers or vehicles for final disposal. (See cut.)

In the new "Jigrit" the solids are formed into a bed on a screen plate below which is a box for admission of wash water. Water moves up through the screen plate to open the bed and permit stratification of the solids in accordance with specific gravity. Interruption of the upward flow closes the bed. This alternate opening and closing of the bed not only classifies the particles but the jigging "scrubs" them, freeing adhering organic solids which move to the top strata and pass over the weir with the wash water along with the coarser organic solids. The cleanest grit settles to the bottom of the bed, the screen plate retaining the coarse particles, while the perforations through the screen plate permits the small particles to pass into the box for subsequent discharge as washed grit.

At present the "Jigrit" is made in two sizes: No. 4, having 4 square feet of screen area and a capacity of from 4 to 5 tons per hour of feed. No. 1 "Jigrit" having only one square foot of screen area and a capacity of approximately one ton per hour of feed.

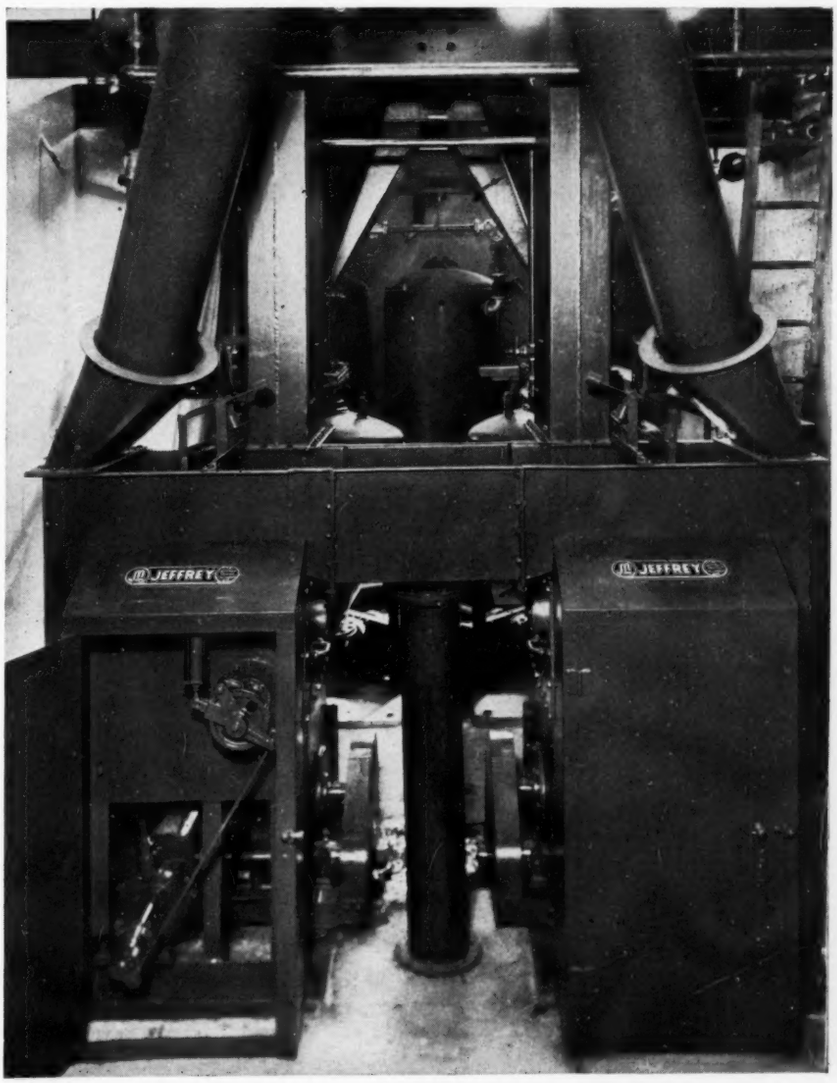
The larger unit (see cut) is provided with a diaphragm positioned below the screen plate and adapted to be moved in a predetermined cycle by a power operated eccentric mechanism. Such movement creates an upward and downward current of water which imparts a breathing motion on the bed. Automatic controls govern the rate of discharge of coarse clean grit from the lower strata of the bed, while maintaining a bed depth within close limits. This bed of grit acts as a filter and prevents the passage of organics with the clean bottom grit. A float positioned in the bed rides the top of the coarse grit strata and moves with each pulsation. As the coarse grit strata increases in depth, the float rises and operates devices to cause rotation of a star type draw. As the coarse grit strata is lowered, owing to withdrawal, the float moves downward and operates the mechanism to stop the ejector, or draw. All washed grit is removed continuously from the box by the perforated bucket dewatering elevator.

The Unit for Small Plants

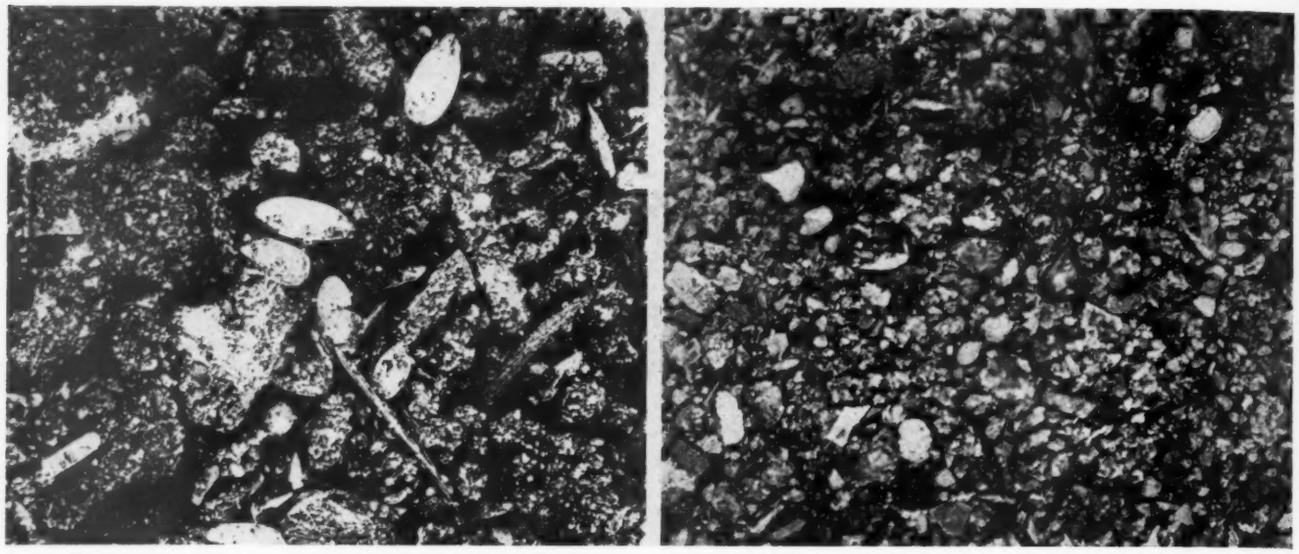
The smaller unit ("Jigrit" No. 1) operates on the same general principle as the heavy duty unit, but does not have automatic controls for the discharge of material from the strata of coarse grit. In this unit the bed of grit is formed in a basket hung from the drive shaft by eccentrics. In operation, the basket moves in a fixed cycle. (See cut.) As the basket moves down, water is forced through the bed to open it, this operation allowing the fine grit to pass the perforations of the screen plate while the coarse washed grit is retained by it. This unit, however, has a float and an indicator by which the operator can determine when coarse grit should be withdrawn. The grit draw at the end of the screen plate is movable from a closed position to an open position by manual operation. In "Jigrit" No. 1 all washed grit passes to the hopper below the basket and is continuously removed by a screw conveyor.

What Constitutes Clean Grit

Results of grit washing methods are usually expressed in the



New Jig Type Grit Washers—The "Jigrit"
These Classifying Grit Scrubbers Provide Automatic Wash Control and Turn Out Grit Containing Less than 0.5% Putrescibles.

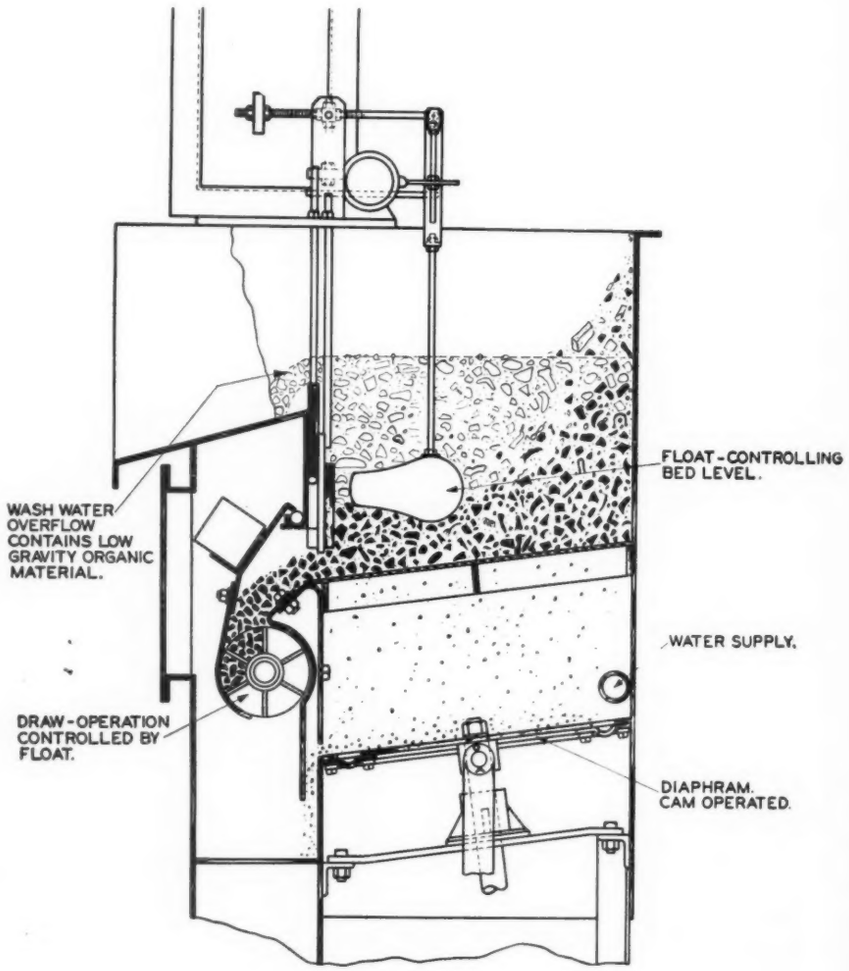


The Crude and "Jigritted" Product
In which 4.5% putrescibles (including seeds and the like) have been reduced to 0.4% to yield a nuisanceless product of pleasing appearance.

reduction of putrescible solids, the latter being determined with "Dazey Churn Test," as given in the July, 1930, issue of Sewage Works Journal. Such determinations alone do not, however, convey the true efficiency of the method for the reason that large organic solids, such as, seeds, macaroni, spaghetti, worms, etc., are not adequately disintegrated in the test and are retained in the Dazey Churn as residue, thus being recorded as inorganics rather than organics.

By using the Jigrit method and equipment, reductions in putrescible solids as high as 90% can be obtained with little or no loss of inorganic solids with the overflow. It is believed that unwashed grit removed from well designed, mechanized grit chambers contains an average putrescible solids content of approximately 5 per cent. If this be reduced 90%, only 0.5% putrescible solids remain in the washed grit. In addition, the removal of the difficult coarse or large organic solids makes the grit much more pleasing in appearance (see cut) and, thereby, more suitable for use as fill or walkaways about the plant; also, reducing to a minimum the cost of disposal.

Results obtained in a series of tests using Jigrit No. 4 equipped with automatic controls, are as follows: The average putrescible solids content in the feed was 4.77%, while the average washed grit contained only 0.65% putrescibles. The photographs of the samples picture the degree of cleanliness and pleasing appearance of the jigged grit. The differences in the Dazey Churn residue of feed samples and the washed grit may be found also in ash determinations. In this series of tests the average residue ash was 69.6%, while the washed grit ash averaged 75.6%, an increase of 6%, due to the reduction of organic solids in the washed grit.

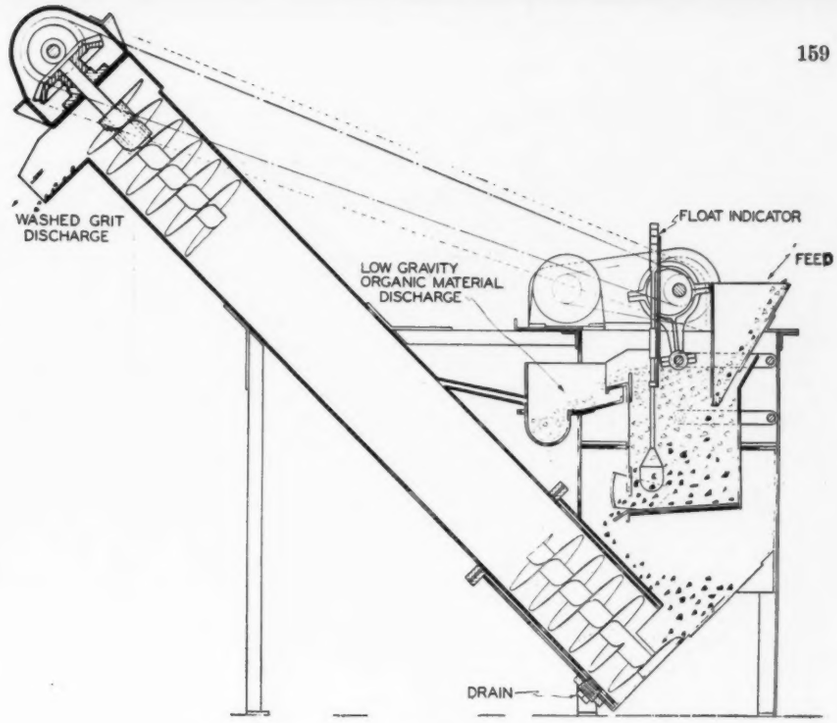

FLOAT-CONTROLLING BED LEVEL.
WASH WATER OVERFLOW CONTAINS LOW GRAVITY ORGANIC MATERIAL.
WATER SUPPLY.
DRAW-OPERATION CONTROLLED BY FLOAT.
DIAPHRAM. CAM OPERATED.

The Heart of the "Jigrit"
The pulsating diaphragm causes the grit bed to breathe and classify the particles. Coarse grit remains above the perforated false bottom, while wash water passes up to sweep out the mascerated organics, and fine grit drops through the perforations. The depth of the coarse grit bed is automatically maintained by the float mechanism which controls the star type draw gate.

A thorough test of the small, manually controlled "Jigrit" No. 1 was conducted recently. These tests proved that this unit can be manually controlled to produce results equal to those from the automatic unit. For the series of tests the average feed contained 4.5% putrescible solids and the washed grit averaged of only 0.4% putrescibles, a reduction of 91%.

"Jigrit" No. 4 requires about 20 square feet of floor area and a minimum of approximately 14 feet of height. It requires only 2 h.p. for operation and is a self-contained unit. Approximately 40 gal. of wash water per minute are required. Where preferred clarified sewage or plant effluent may be used as wash water.

Jigrit No. 1 requires about 16 square feet of floor area and less than 7 feet of head room. It is a complete factory assembly, requires only ½ h.p. for operation and only 10 gallons of washing liquid per minute.



The Non-Automatic "Jigrit" for Smaller Plants

SIZE AND SLOPE OF SEWERS

By Simplified Formulae Approximating Kutter's

By BENJAMIN EISNER, Chief Engineer
Clay Sewer Pipe Association, Pittsburgh, Penna.

KUTTER'S formula for computation of flow velocities in open channels is preferably solved by graphs to avoid the lengthy arithmetic necessary to compute "C." Because pipe sewer problems are but a small portion of the wide field of application of the Kutter formula, and since extreme precision is not warranted in sewer and drain design, it is possible to approximate the Kutter formula for such problems by matching a simple curve to the complex one expressed by the formula. Such matching is possible only because short lengths of the curves are used. For sewers and drains "n" is usually taken at either 0.013 or 0.015; "v" is required to exceed 2 feet per second, pipe diameters generally fall between 8 and 36 inches, and slope rarely reaches 10 per cent grade.

If within these limitations, values for "s" are plotted against "d" for any given velocity, the resultant curve closely approximates a hyperbola. If too, for later convenience, "s" is measured in feet per thousand, and "d" in inches of diameter, the hyperbolic curves may be expressed in the following manner:

$$\text{For "n"} = 0.013: \quad v = 1/2\sqrt{s}\ \sqrt{d-4.5} \qquad (A)$$

$$\text{For "n"} = 0.015: \quad v = 4/9\sqrt{s}\ \sqrt{d-5} \qquad (B)$$

Of course, both cases apply only to pipes running full or half-full. Accuracy of results by use of these approximations is indicated in tables I and II which cover the range of application outlined above.

Use of these approximations with a slide rule is believed to be quite as rapid as use of charts for the solution of Kutter's formula. Although there is a slight loss of accuracy, the error thus introduced is less in amount than the errors accompanying estimates of future flow and choice of coefficient "n."

So far, no mention has been made of the term Q as used in Q = Av. If Q is measured in million gallons daily, if "d" is used as before, to denote pipe diameter in inches, and if the pipes are considered to run full, Q = Av can be reduced to

$$d = 17\sqrt{\frac{Q}{v}} \qquad (C)$$

which is easily converted to a form suitable for rapid determination of pipe size for minimum self-cleaning velocity. If velocity of two feet per second is the lower limit, this expression reduces to $d = 12\sqrt{Q}$, for full flow, which can be further simplified by expression as "diameter in feet for 2 feet per second velocity equals the square root of the full flow in millions of gallons daily." Similarly the previous approximations for "s," at 2 feet per second velocity reduce to the fllowing—

$$\text{For:} \quad (n = 0.013) \quad s = \frac{16}{d-4.5} \qquad \text{For:} \quad (n = 0.015) \quad s = \frac{20}{d-5}$$

Thus for minimum self-cleaning velocities determination of diameter and slope is rapid.

Commitment to memory of approximatoins (A) and (C) permits rapid sewer and drain design when flow charts are not readily available. For the slight loss of accuracy, speed and convenience are gained. In practical use "d" is assumed and approximate "v" determined as in (A).

This value is substituted in (C) and the result "d" is compared with the assumption. With slight practice the second trial value of "d" will be found to satisfy both equations within practical limits.

Comparison of Velocities of Flow in Conduits (Running Full or Half Full) Computed by Approximate Formula and Kutter's Formula

TABLE I (n=0.013)

SLOPE (Feet per 1,000 ft.)	DIAMETER (Inches) 8	12	18	27	36
0.3			**1.9** 1.0	**1.3** 1.3	**1.6** 1.6
1	**0.9** 0.9	**1.4** 1.4	**1.8** 1.8	**2.4** 2.5	**2.8** 3.0
3	**1.6** 1.7	**2.4** 2.4	**3.2** 3.2	**4.1** 4.3	**4.9** 5.2
10	**3.0** 3.2	**4.3** 4.3	**5.8** 5.8	**7.5** 7.8	**8.9** 9.6
30	**5.1** 5.5	**7.5** 7.5	**10.1** 10.1	**13.0** 13.5	
100	**9.4** 10.0	**13.7** 13.8			

TABLE II (n=0.015)

SLOPE (Feet per 1,000 ft.)	DIAMETER (Inches) 8	12	18	27	36
0.3			**0.9** 0.9	**1.1** 1.3	**1.4** 1.6
1	**0.8** 0.6	**1.2** 1.1	**1.6** 1.7	**2.1** 2.1	**2.5** 2.5
3	**1.3** 1.4	**1.9** 1.9	**2.8** 2.7	**3.6** 3.6	**4.3** 4.4
10	**2.4** 2.6	**3.4** 3.6	**5.0** 4.9	**6.6** 6.6	**7.8** 8.1
30	**4.2** 4.5	**5.9** 6.2	**8.8** 8.5	**11.4** 11.2	**13.6** 13.8
100	**7.7** 8.2	**11.7** 11.3	**16.0** 15.5		

Bold face figures indicate approximation. Light face figures are results from chart of Kutter's Formula.

THE JEFFREY MANUFACTURING COMPANY

SANITARY ENGINEERING DIVISION

996-99 North Fourth Street, Columbus, Ohio

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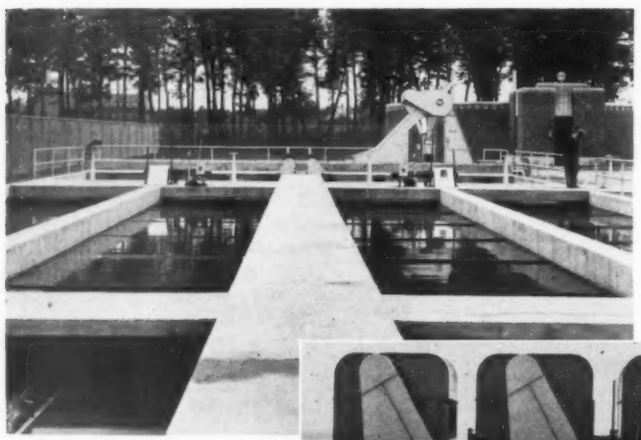
PRODUCTS: Sludge collectors, bar screens, scum collectors, grit collectors, grit washers, Floctrols, Screenings Grinders, Garbage Grinders, Chemical Feeders, Dried Sludge Grinders, Sludge Elevators, Conveying and Elevating Equipment, Chains—Etc. Catalog No. 703.

SLUDGE COLLECTORS (Conveyor type)

Rectangular tanks make very efficient settling units. With proper baffling it's possible to get uniform distribution of influent over cross section of tank. Jeffrey collectors are the simplest form of conveyor—will remove sewage sludge efficiently and economically. You'll find Jeffrey sludge collectors in some of the largest sewage disposal plants in the country.

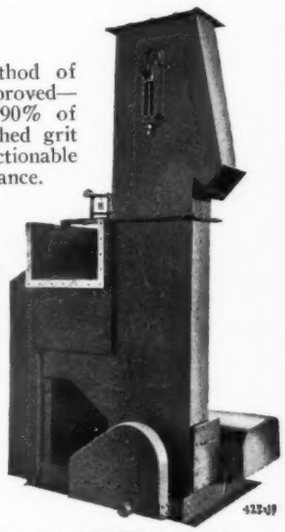


GRIT WASHERS

(Patented)

The Jeffrey JIGRIT method of washing grit has been proved—will remove from 70 to 90% of putrescible solids, the washed grit being free from objectionable odors or unsightly appearance.

Built in two sizes; the No. 1 (below) with a capacity of approximately 1 yard per hour; the No. 4 JIGRIT (right) with capacity of about 4 yards per hour.



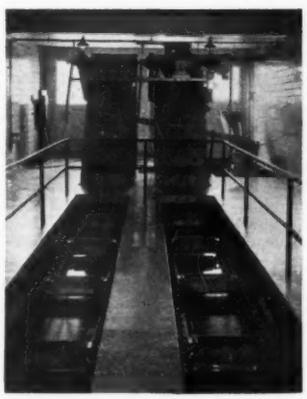
The Jeffrey No. 1 JIGRIT is hand controlled with totally enclosed motor. Requires small amount of floor space. The No. 4 has full automatic controls—for large plants.

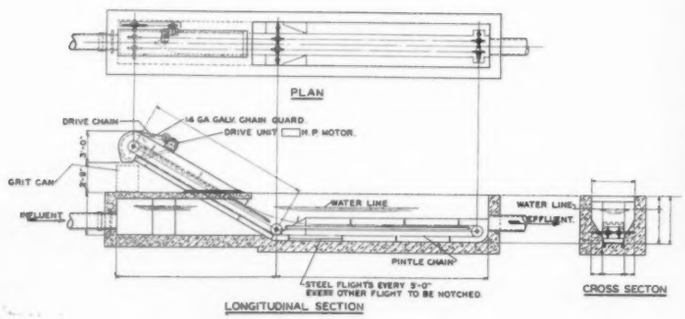
GRIT COLLECTORS

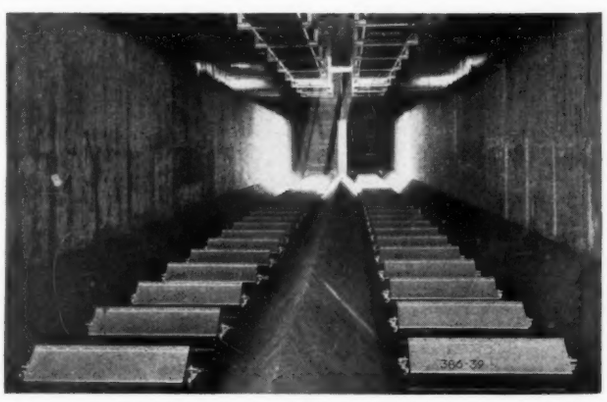
Jeffrey builds three types for grit channel mechanism: scraper, V-bucket and a combination of the two. The scraper type is shown in drawing below—it continues up the incline. Notched flights between conveying flights stir silt to remove organic matter.

Above—Scraper type discharging into a vertical V-bucket at the Bowery Bay, N. Y., plant.

The V-bucket type grit collector with horizontal and vertical runs (right) is installed at the Manitowoc, Wisconsin, plant. This is ideal where space is limited or where grit must be carried to a considerable height. Perforation of buckets will allow free water to drain back into channel.

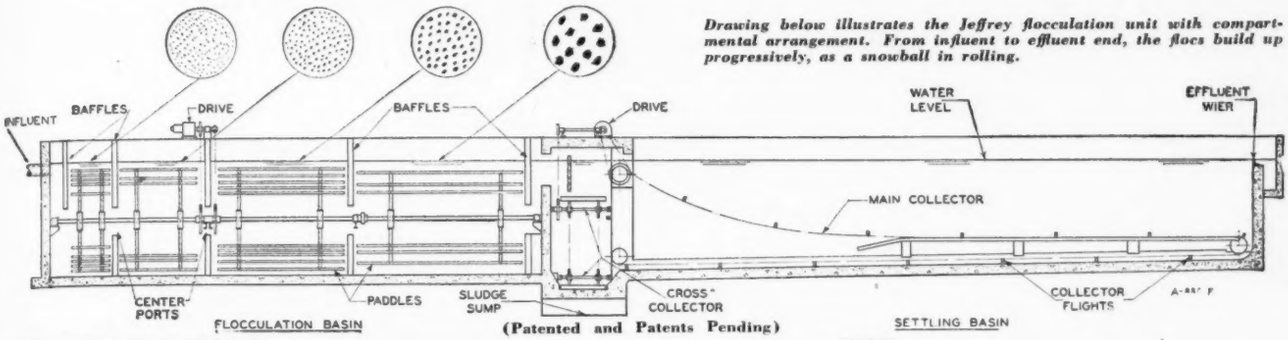






Above—Jeffrey V-bucket collectors installed in the Detroit, Michigan, plant, in which are also Jeffrey screens, grinders, grit and sludge collector equipment.

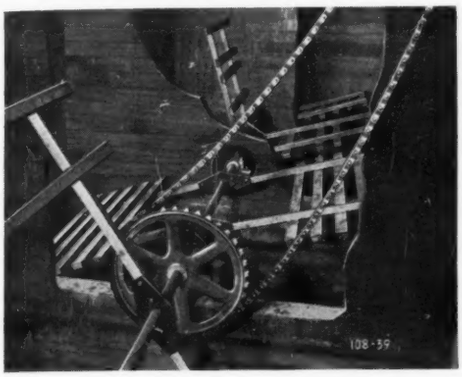
THE JEFFREY MANUFACURING COMPANY



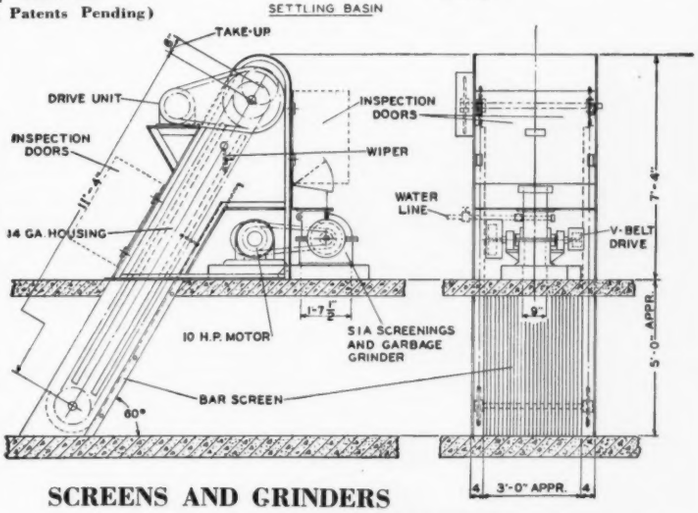
Drawing below illustrates the Jeffrey flocculation unit with compartmental arrangement. From influent to effluent end, the flocs build up progressively, as a snowball in rolling.

(Patented and Patents Pending)

JEFFREY FLOCTROL—a new process for pre-clarification of turbid waters. It obtains substantially complete removal of solids in the sedimentation basin using a minimum of chemical coagulant.



This Jeffrey process can be used for treating sewage and waste water, water softening and industrial processing. Low first cost—maximum retention of flow—minimum chemical cost—tapered mixing—progressive build-up of stable flocs—continuous sludge removal in separate basin—no mechanical adjustments. See drawing above.



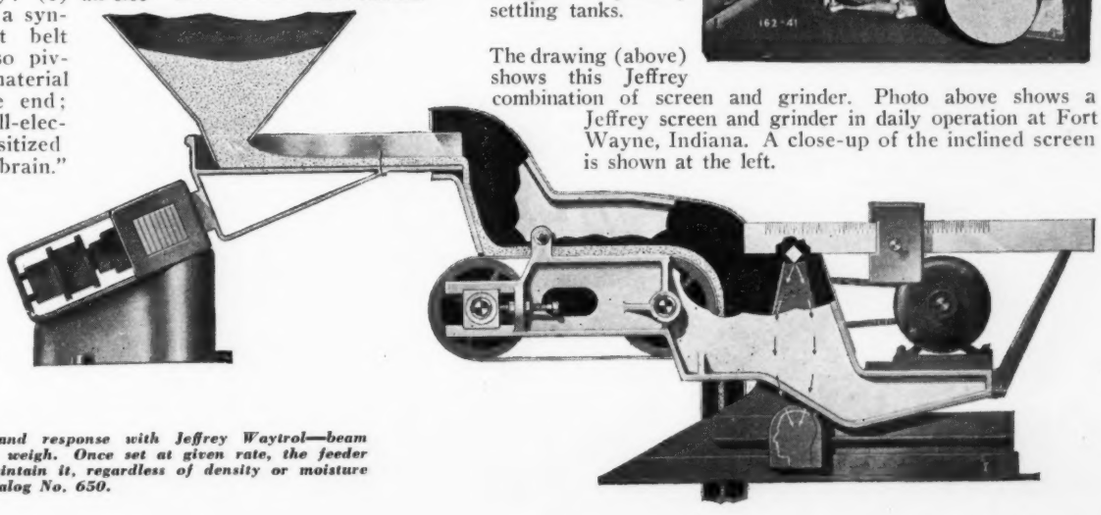
Full partitions except for openings at the axis (photo above) of the shaft is the most practical way of minimizing short-circuiting.

Jeffrey inclined bar screen (right) cleaned by rake mechanism, teeth passing between the bars as rake moves upward. Operation is entirely automatic, controlled electrically.

JEFFREY WAYTROLS

Continuous and accurate weigh-feeding dry chemicals is assured with the Jeffrey Waytrol. It will feed and weigh to within 1% of the required amount—rate of feed can be varied over a wide range by merely turning a knob.

As diagram below shows, the Waytrol embodies three features to insure super-accuracy: (1) all-electric feeding; (2) a synchronous weight belt on scale beam so pivoted to receive material at most sensitive end; (3) automatic all-electric control sensitized through "electric brain."

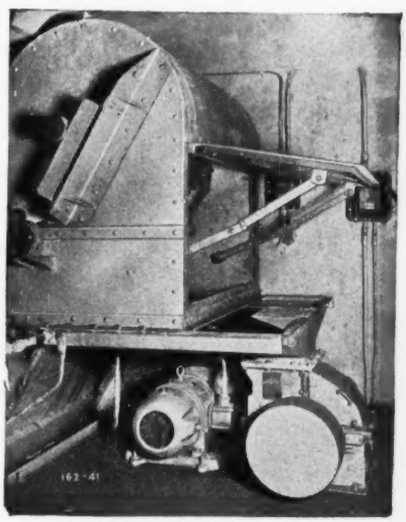


Reg. U. S. Pat Off.

Maximum accuracy and response with Jeffrey Waytrol—beam does no work except weigh. Once set at given rate, the feeder will automatically maintain it, regardless of density or moisture change. Send for Catalog No. 650.

SCREENS AND GRINDERS

Efficient apparatus for the removal of suspended matter and disposal is this Jeffrey combination—Screen and Grinder. It will take care of the final disposal of sewage screenings so important in the treatment of sewage. Screenings are collected and disposed of by reducing them to a pulp and returning them to the sewage. Pulped screenings will readily pass the pumps and settle out with the sludge in primary settling tanks.



The drawing (above) shows this Jeffrey combination of screen and grinder. Photo above shows a Jeffrey screen and grinder in daily operation at Fort Wayne, Indiana. A close-up of the inclined screen is shown at the left.

MORRIS MACHINE WORKS, BALDWINSVILLE, N. Y.

BUILDERS OF CENTRIFUGAL PUMPS, SINGLE- AND MULTI-STAGE, FOR PRACTICALLY ALL PURPOSES SINCE 1864

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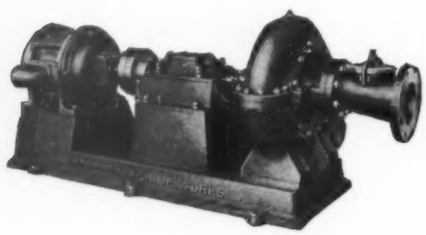
Canada: Storey Pump & Equipment Co., Toronto; F. H. Hopkins & Co., Montreal. Export Office: 50 Church St., New York City.

Morris Non-clogging Sewage Pumps are built in both vertical and horizontal types, in sizes up to 54 in., with open, semi-open or enclosed impeller, single or double suction, and for any type of drive or combination of drives.



Morris standard horizontal motor-driven non-clogging sewage pump.

In many installations these pumps are operating at efficiencies exceeding 90 per cent, and their special design, accurate workmanship and wear-resisting materials assure long maintenance of high initial efficiency and trouble-free service.

Morris Straightflo Sewage Pump, which has developed efficiencies above 90%

Some of the outstanding features of design of these pumps are as follows:

Casing — Strongly proportioned with ample margins of safety. Single suction types are provided with renewable discs on each side, and double suction types have removable cover to provide accessibility to impeller and pump shaft without disturbing pipe connections. A conveniently located handhole on the outside of the casing permits easy inspection of pump interior.

Morris high-speed vertical non-clogging sewage pump.

Impeller—Specially designed to pass pulp, semi-solids and exceptionally large solids without danger of clogging up or breakage. Impellers are carefully hand-finished after being accurately machined and are tested and adjusted for rotative balance.

Shaft—Extra heavily proportioned to transmit maximum power and withstand operating stresses without vibration or distortion. Ground to close limits and protected by a bronze sleeve through the stuffing box to prevent wear or corrosion.

Stuffing box — Exceptionally deep with ample packing space and sealed by clear water. Readily adjustable in both horizontal and vertical types and fully protected against sand, grit, sewage, etc.

Large Morris Vertical Screw Pump.

Bearings— Steady bearings are of heavy duty double-enclosed ring oiling type, rigidly connected to the pump casing and arranged for ample and positive lubrication. Thrust bearings are substantially built of roller or ball type, ample in size for maximum thrust which could be encountered, and are readily adjustable.

OTHER TYPES OF PUMPS

Morris Machine Works also builds single and multi-stage pumps for municipal water supply and fire protection, boiler feed, condenser circulation, drainage, corrosive liquids and abrasive mixtures of all kinds, and for general plant service.

Also hydraulic dredges for cleaning out, enlarging or deepening municipal reservoirs, improving waterways and shore lines, park developments, filling in, sand and gravel production, etc.

Bulletins sent on request.

Screw type impeller for Morris Sewage Pump. Used for large-capacity pumps and has developed remarkably high efficiencies.

MORRIS
CENTRIFUGAL PUMPS

SEWAGE AND SLUDGE PUMPING

By HENRY RYON
Senior Engineer
State Department of Public Works, Albany, N. Y.

Part I—Sewage Pumping

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multistage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a

common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics. Each manufacturer apparently believes that the transmission used by him is the best, but in practice there seems to be little difference.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No mater which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable ve-

locity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interoir.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulations seem to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a small pump may be used to supply water to the seal. Grease seals and other special devices are sometimes used but are not as satisfactory as water seals.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. I), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

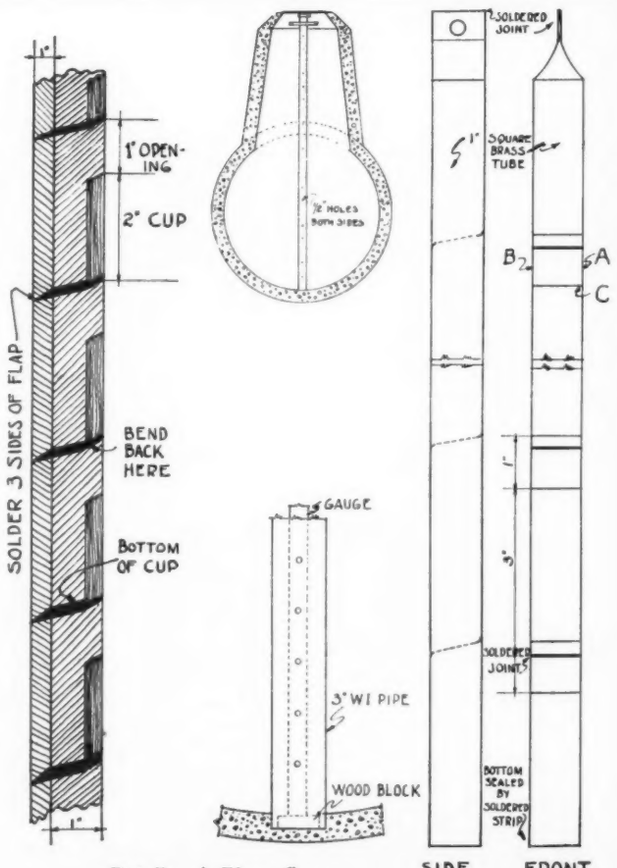
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

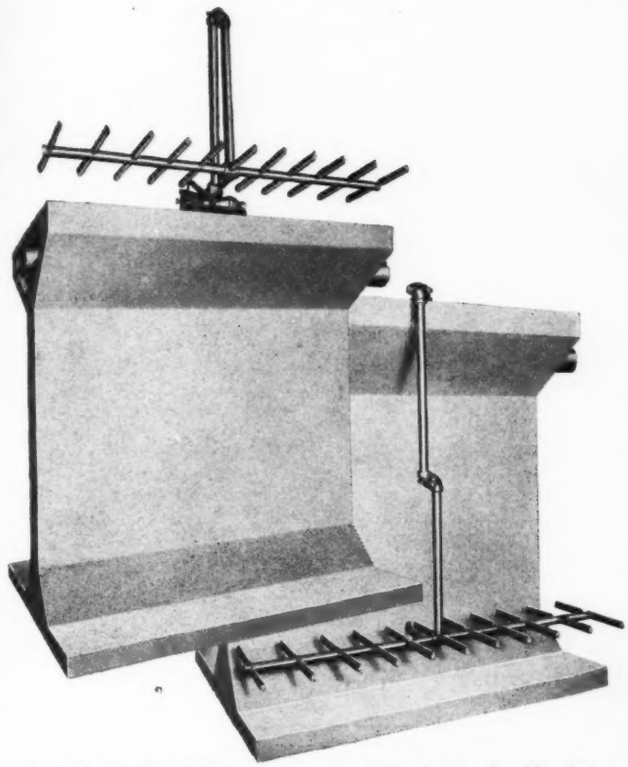


Fig. 2914—Swing Diffusers
Controlled aeration for the Activated Sludge Process. For towns of 4,000 and up. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation. Ask for Bulletin 175.

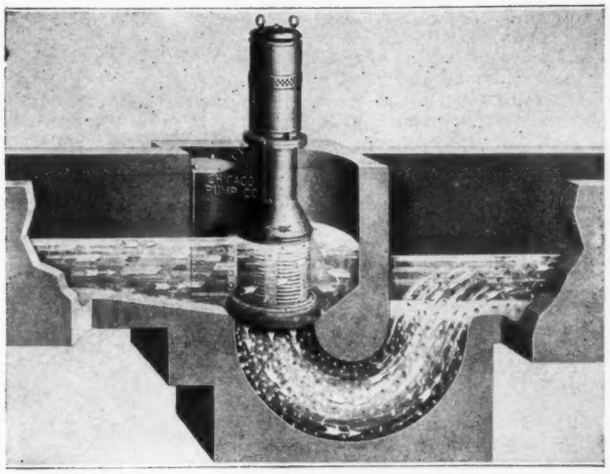


Fig. 2202—Comminutor
Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel.

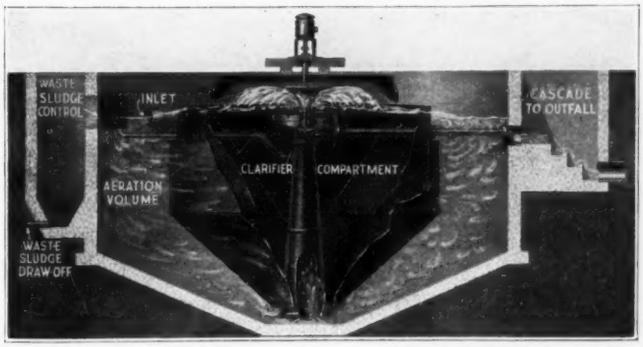


Fig. 2349 (right)**—Combination Aerator-Clarifier**
providing complete treatment of sewage without odor nuisance and with minimum manual operation. Ideal for housing projects, small camps, institutions and small towns. Over 65 units operating successfully. Ask for Bulletin 128-K.

Fig 2504—Vertical Open-Shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

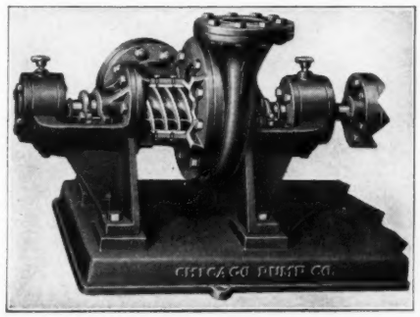


Fig. 1860—Scru-Peller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.

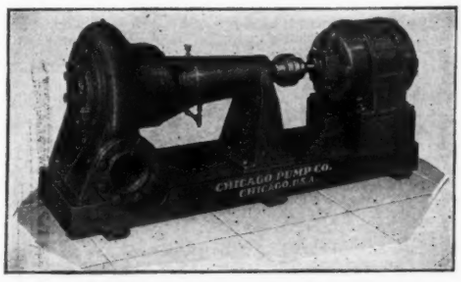


Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

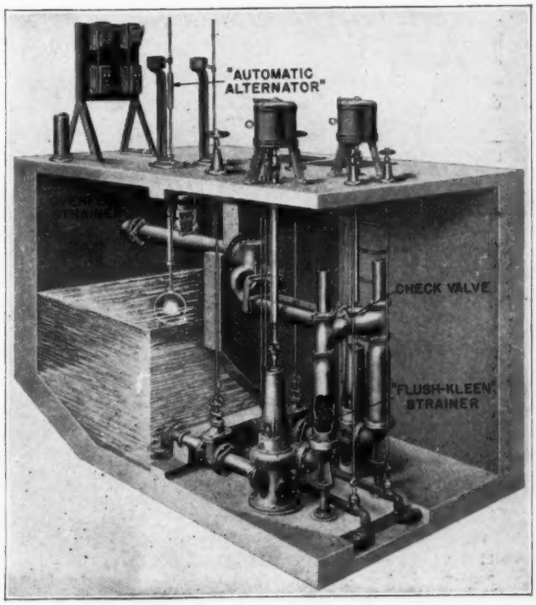


Fig. 2038—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

SEWER CLEANING WITH RUBBER BEACH BALLS

By A. M. RAWN, C.E.*
Los Angeles, Calif.

DURING construction of the sewer lines of the Los Angeles County Sanitation Districts, the problem of cleaning sand and debris from newly constructed lines gave rise to the trial of pneumatic rubber beach balls for this purpose. The use of beach balls was the outgrowth of the usual trial and error methods of using pull through devices, sluicing, use of fire hose and the like.

What is termed a beach ball in this narrative is the ordinary type of commercial pneumatic rubber ball commonly used at play grounds, at beach resorts and otherwise. The rubber is thin and the ball can be blown up to varying degrees of inflation at will. As furnished commercially, the balls have no covering and consist simply of elastic rubber. These balls are manufactured in sizes (diameters) of 6 to 30 inch diameter when fully inflated.

Procedure

For use in cleaning sewers the ball is first inflated and then wrapped in a covering of canvas or burlap, the edges of which are sewed together. A trail-line a little longer than the distance between manholes is then attached securely to the covering. The size of the ball and its covering should be such as to fit fairly snugly into the sewer leaving the downstream side of the manhole.

Immediately the ball is kicked into the pipe, sewage commences to back up in the manhole and continues to increase in depth until such time as its pressure is great enough to force water *under* the ball. (See sketch.) The ball then commences to move downstream through the pipe. Acting as a compressible floating plug it affords enough obstruction so that a continuous high velocity jet spurts under and to some extent around the balls, thereby sluicing all movable material ahead to the next manhole.

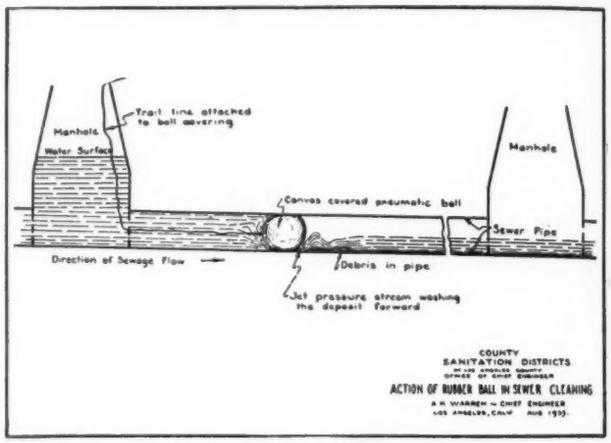
Should the ball encounter an obstruction which is immovable (for instance a joint fin or the like), it merely indents to the necessary degree and moves forward. About the only fixed obstruction which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe. Brick, stones, bottles, loose metal parts, broken pieces of pipe, sand, gravel and settled sludge are easily moved ahead.

If the ball stops momentarily, a pull on the trail-line is usually sufficient to set it again in motion and if the pipe is quite dirty the trail-line can be snubbed to a step in the upper manhole and the ball's progress retarded to the required degree as the lower manhole is approached, thus giving time for compelte removal of accumulated debris which the sewage has piled up ahead of the ball.

Much time may be saved by conserving the sewage pressure-head as the ball floats into the lower manhole. Just as the ball comes into view at the lower manhole, the snubbed trail-line is cast off and as the ball floats into the lower manhole with the gush of sewage, it is immediately kicked into the lower (outlet) pipe. The trail-line is picked up by fishing for it and the work proceeds as before.

In ordinarily dirty lines three men are employed as a crew and have cleaned in excess of four miles of sewer pipe in an eight hour working day.

The canvas covering serves two purposes: it permits ready attachment of the trail-line and also affords a measure of protection against puncture by razor blades, glass and sharp metal particles in the sewage sediment. The operation and maintenance crew carry along inner tube vulcanizing patches and small holes in balls are readily repaired on the job without much loss of time.



Sketch Showing Action of Beach Ball During Sewer Cleaning

A Real Test

As a measure of the utility of this method of cleaning, one outstanding example will be noted. A 24-inch diameter reinforced concrete pipe inverted siphon carries the sewage of one main under the Los Angeles River flood control channel. The siphon is about 800 feet in length. A ball, with trail-line attached, was inserted in the upstream end of the pipe; and, although, it took thirty-six hours to work its way through, there appeared ahead of it about a truck load of sand, gravel, bricks and boulders as well as a half-dozen flash boards which had dropped into the sewer at the upstream gate. The ball was put through again immediately and appeared at the outlets in less than an hour.

*Chief Engr., Los Angeles County Sanitation District, Los Angeles; Associate Editor W.W.&S.

NOZZLE REPLACEMENT ON TRICKLING FILTERS

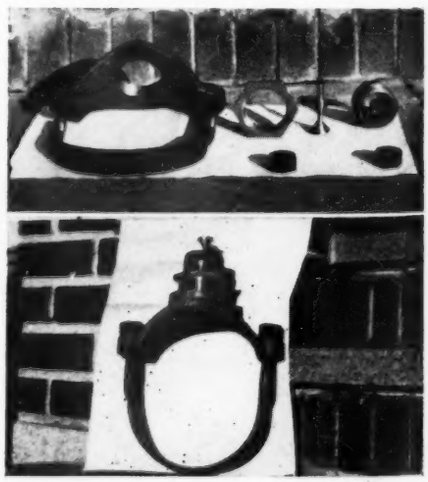
By ROY S. LANPHEAR
Worcester, Mass.

FLUSHING of the lateral distributors of the trickling filters at Worcester is done once each week by removing the end nozzle in each line (several at a time), and allowing the dosing tank siphons to operate once or twice. The threads in the pipe openings, into which the nozzles were screwed, were destroyed after a few months of this routine operation. Cast iron pipe, brass nozzles and a sewage containing strong acid and alkaline industrial waste liquors were also factors in such destruction.

Saddles, with washers and U-bolts, were first used. When the threads in a saddle gave out, a new saddle was installed. This operation proved successful and was used for some time. Additional purchases indicated that while the method was a success, the expense was quite an item in the cost of filter operation. Apparently galvanic corrosion was at the root of the thread wearing difficulty.

A later improvement was the use of a 2½x2-inch brass bushing in the saddle opening. This left the contact of the iron and brass threads undisturbed when removing the nozzles. No difficulty is now experienced and saddles with the bushings have been in use since May 1937. In lots of 200 the cost of the saddles, strap-type U-bolts, and bushings, was 84, 58½ and 47 cents each, respectively.

The accompanying cut shows the several component parts of the successful assembly.



MAINTENANCE OF SEWAGE PUMPING STATIONS

By A. L. SODEN
Chief Operator
Sewage Treatment Works, Trenton, N. J.

THE writer, after some fifteen years of experience with seven pumping stations containing twenty-seven pumps with capacities from 50,000 to 11,000,000 gallons per day, has come to the very definite conclusion that maintenance of this type of equipment involves three main objectives, proper lubrication, cleanliness, and frequent detailed inspection. At first thought the first two involve the last, but dumping oil or grease into a machine plus wiping it off do not constitute inspection any more than feeding and bathing a baby is a substitute for a doctor's periodic checkup. The point I wish to drive home is that good maintenance catches trouble *before it starts* and postpones indefinitely the day when the machine must be scrapped for any other reason than obsolescence.

The use of good oil and grease is a very essential item. Lubricants not suited for each particular piece of equipment may, however, no matter what they cost, do more damage than a cheap oil of a suitable character. It must be kept in mind that too much oil in many cases tends to cause more wear than too little, due to the fact that dust, always present in the air, will mix with the oil and act as an abrasive when passing through the bearings. This situation is more serious in a gravity or pressure feed system than with the oil reservoir type.

It is axiomatic that efficient lubrication is a matter of using good lubricants, properly selected, in the correct quantity, at the right intervals. Neglect or omission of any of these factors means accelerated depreciation and breakdown.

Low Price—High Cost Lubricants

Cheap lubricants are costly in the long run and if the average operator would only sit down and figure the total saving per year in a few cents less per quart of oil, or pound of grease, as against many dollars for new bearings, sleeves and shafting, damaged by cheap "bargain" goods he would realize that the best is none too good. We had an example of this in Trenton where for a time the purchasing department paid twenty-seven cents per gallon for automobile oil which was bought on a price basis.

Even though good materials are supplied, one must be certain that they are of the right weight, viscosity, etc., for the job and the only way to be certain is to follow the manufacturer's recommendation for the unit being serviced, or, if this is not available, call in a lubrication engineer from one of the big companies. You will note the word "engineer"—beware of smooth talking salesmen with trick oils that never wear out, made by some magical process and sold at high prices under a fancy name.

It may seem proper to the average person that as long as the correct amount of oil or grease is in a bearing and no noise or heat is noticeable that the machine could run indefinitely. This, however, is *not* true as many pieces of equipment are installed in damp wells where condensation is present, the worst enemy of any bearing no matter what type lubrication is used.

Gravity or pressure feed lubrication systems with an oil filter in the line do not require as much attention as equipment having the oil reservoir. A good method to follow is draining and flushing these types of bearings and refilling with new oil at least every six months, and in some instances where water is present, every three months.

Shaft Bearings

Many line shaft bearings are made for grease lubrication and can be run with safety on equipment in small booster stations for about a year before flushing and repacking with new grease. We have found through past experience that it is sound economy to remove the bearings from the shafts and wash thoroughly in gasoline or kerosene, both the bearings and the oil reservoirs, thus removing all traces of moisture, old grease and foreign matter at least once a year. This procedure should be more frequent in a plant where the equipment is running continuously. Care should be taken to put the right amount of grease in a bearing as too much causes bearings to heat through increased friction.

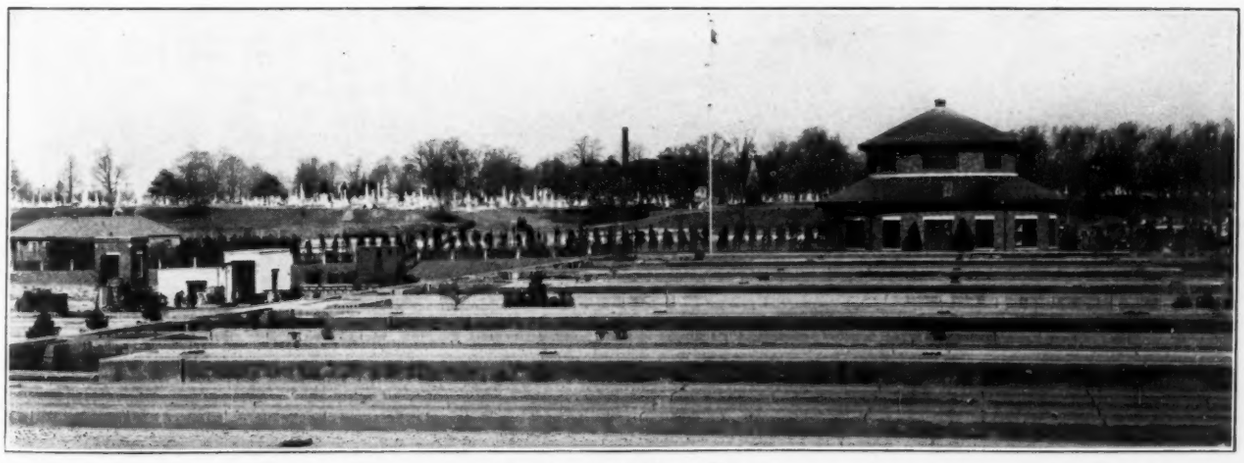
An oil filter, if used, should have at least twice the capacity of the lubricating system. This unit is used to separate the water and oil in a primary chamber and, in a secondary compartment, dirt in the oil which has a tendency to collect in bearing boxes, and any scaling which may develop in the oil lines. Such is particularly true if the latter are constructed of iron or steel pipe and fittings. Copper tubing or brass pipe and fittings are the only materials which should be used, thus preventing damage to bearings due to the stoppage of the oil grooves by pieces of rust or scale which come from iron or steel pipe, even though these be galvanized.

The matter of cleanliness around any machinery is a very important factor not only for looks but for the good of the equipment. It must be kept in mind that next to water, dust and dirt are the most destructive enemies to motors, bearings, controllers, starting switches, and many other pieces of electrical equipment that are found in a pumping station.

Motor Care

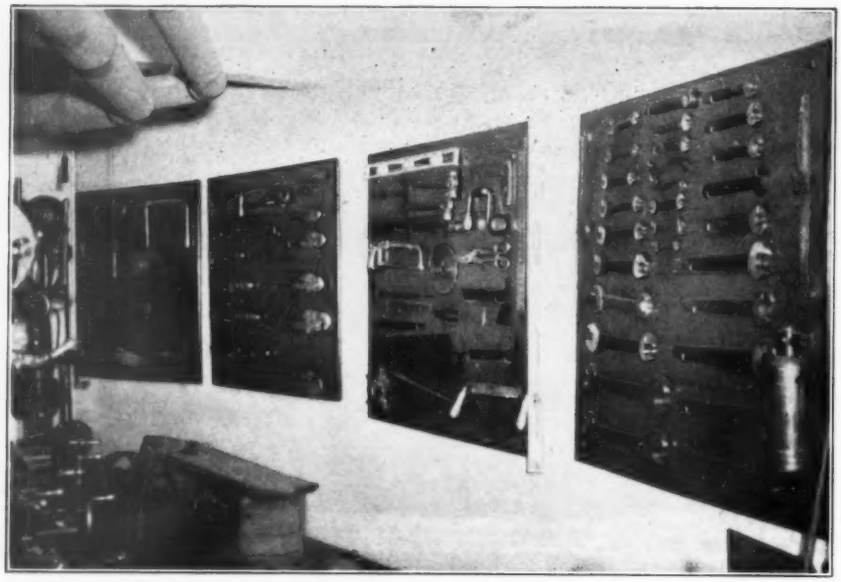
Motors must be kept free from water, oil and dirt. A good method of cleaning the interior is with compressed air or a bellows. When using compressed air care must be taken to be certain there is no moisture in the storage tank that could escape through the nozzle used for cleaning. Cleaning motors with compressed air should never be done by an amateur. The older the motor the more brittle the insulation and high pressure air through too small a nozzle can be very destructive to the motor insulation.

An excellent plan is to give the motors a thorough cleaning once every six months and at least once every two years give the windings a coat of a good grade of insulating varnish. At this time the bearings should be thoroughly cleaned and refilled with new oil, or repacked with new grease.



The Treatment Works of Trenton

One Battery of Imhoff Tanks and Pumping Station



Shop and Tool Room of the Main Pumping Station—Trenton, N. J.

Contactors

Contactors often give an operator more or less trouble due to particles of dust becoming imbedded in the contact fingers. It is a good plan never to use any lubricant on the main contact tips which are mostly constructed of copper, as oil or grease has a tendency to shorten the life of these items. If they should become pitted or burned, which in many cases cannot be avoided, remove the contact tips and clean up with a smooth file or very fine sand paper. Care should be taken when attempting to clean contacts in place not to bend or misalign the parts.

If the operating force is large enough it is a good policy to assign different parts of the equipment and pumping station to the shift operator or oilers and set up a system whereby the entire equipment and pumping station is cleaned at least once every month from top to bottom, besides the daily routine sweeping, mopping and dusting.

Insurance in Cleanliness

This, however, does not mean that the equipment should be dismantled and reassembled but it is important to get the dust and dirt, which is on the surface, before it has a chance to penetrate to the vital parts of the machinery. It will not work a hardship on any member of the operating force to do a little cleaning now and then, no matter what the title of the job he holds. By doing this a man gets around and has a chance to inspect parts of the equipment which he otherwise would not give a second glance unless trouble should develop in that particular spot.

To be clean is to be free from dirt, odor and keep tidy. There is no reason why a pumping station should not be kept clean, no matter what type—water or sewage. A little attention to cleanliness will result in continued satisfactory operating results and enable the operator to get the most efficient results and best service out of the equipment for many years.

Thoroughness

Maintenance of any piece of equipment should be as thorough as a doctor's examination, not just the usual haphazard method of looking or just glancing in the direction of the machinery. A system of inspection should be drawn up and followed to the letter.

Commutators and Brushes

Detailed inspection of motors, shafting, electrical equipment, pumps and piping should be done by men qualified through years of experience for they know what to look for in each unit.

In the case of single phase motors, commutators become rough and burned through continuous operation, dust and oil accumulating being the chief cause. Commutators should be polished with sand paper on a flat block of wood so that the insulation between the segments will be cut back even with the copper. Under no circumstances use emery cloth or emery paper in this operation. A commutator hone with the correct radius is the most efficient tool to use for this purpose.

The brushes should move freely in the brush holders, with the proper spring tension as recommended by the manufacturer. If they do not move freely, a good contact with the commutator will not be made during the starting period. Both brushes and brush holders should be inspected periodically to see that the brushes have not worn down to a point where they are so short that the brush holder springs cannot press the brushes against the commutator, thus causing burning of the brushes and commutator through arcing.

Motor-cleaning

It is a good policy in the case of single phase motors, having a short-circuiting device, to overhaul once every year. Motors of this type are hard to clean if not dismantled and every part thoroughly washed. There should never be any trouble at this point except for an abnormal accumulation of dirt or frequent overloads in excess of the maximum capacity of the motor.

The normal running temperature of an electric motor is considered a few degrees above the room temperature and should never be allowed to exceed the general standard of forty degrees centigrade above surrounding atmosphere. Motors will carry a full load continuously with no cause for concern if the room is well ventilated. Overloads or undue friction in the bearings will cause the temperature to rise and should be investigated immediately to remedy the trouble.

Motors of different sizes have their own peculiar sound when running, so an operator after a time will become accustomed to this sound and should any noise not characteristic to the motor develop, he will immediately detect it and look for the trouble and remedy it before any damage has been done.

Shafting and Bearings

Shafting in any plant requires attention more often than other parts of the equipment, to insure the longest possible life of the shaft and the shaft bearings. Shaft alignment may be as true as it is humanly possible to make it, but it will not necessarily stay aligned. A bearing wearing due to friction may cause a slight whip in the shaft and be transmitted to the other shaft bearings, thereby causing added play from vibration. A periodic check of the shaft alignment is most advisable.

Bearings on any shafting should be painted a light color, so when a bearing gathers too much heat the paint will discolor and can be detected immediately Many plants have a thermal overload device which stops the unit when too much heat develops in any shaft bearing. The operator must go to the bearing indicaated on the panel and reset the overload switch before the machine can be started again.

In plants which do not have such a device to depend on an operator must go to each bearing and rely on his sense of feeling, even this method will not tell the true story. A thermometer should be used in any and all cases where there is a suspicion of too much heat. Generally after a bearing has carried excessive heat it is too late even for a thermometer, instead a new bearing is indicated, this being true where periodic inspection is deficient.

When a shaft bearing becomes worn, no matter how little it is false economy to leave it in service. Worn shafting will vibrate and promote undue wear on both motor and pump bearings where direct connected. A bearing in this instance would be cheaper to replace than try to get by with, as possibly a whole section of shaft or motor and pump bearings will be ruined in a short time.

In stations that are automatically controlled by float or pressure switches and no attendant is on duty any length of time, it is advisable to paint the shafting to protect it against rusting. No metal will gather rust more quickly than a highly polished piece of steel. By doing this the unit can be wiped off and be kept clean.

Polished shafting should never be cleaned while the machine is in operation. Although a much better job can be done it is a very dangerous practice. Use of emery cloth should be avoided as the residue may enter the shaft bearing boxes and cause trouble. A good cleaning with soap and water and polishing with metal cleaner will give the best results and not endanger the man doing the cleaning.

It is very important to have uninterrupted operation in many

plants, where no standby units are installed. In case of power failure sufficient emergency lights should be available and special jumpers made up for continuous operation in case of burned out starters, float switches, etc.

Emergency Wiring

Rubber covered elevator cable is the most desirable material for emergency wiring, using copper lugs at either end of each wire. This will simplify connecting to the motor and main or branch switches, thereby removing from service the broken starter or float switch. Manual control will be necessary in the case where the float switch is not working. The size of the wire used for jumpers depends upon the size of the motor. This, however can only be applied to small low voltage motors of the "across the line" type. In case of large motors such as 50 HP, 2,300 volt, consult an electrical engineer for advice.

Pump Care

Necessary tools and equipment should be on hand in case of pump failure due to clogged impellers or any overload which would cause fuses to burn out or overload switches to kick out. Any pump being overloaded can be detected by the sudden rise of the ammeter.

Wearing rings in the pump case and on the impeller should be checked occasionally for clearance by using a thickness gauge. Install new rings when the gap has become large enough to impair the efficiency of the pump. New rings installed will improve the pumping capacity, thereby effecting a saving in the electric power consumption.

Packing Pointers

A most important factor, one which can cause much annoyance to the operator and plenty of damage to a pump is the proper size and grade of packing. For pumps handling dirty water—sand and grit—a packing should be selected with some thirty-five per cent lubrication, thus saving the sleeves from being worn too quickly and excessive seepage at the stuffing boxes. No gland should ever be pulled down with a wrench except at such times as to effect the proper seating when new packing is installed. Stuffing box gland nuts should never be more than finger tight, as too tight a packing will cause a braking effect on the pump shaft thereby overloading the motor.

Care should be taken when repacking any piece of machinery to see that the strands do not twist while being forced to the bottom of the stuffing box. Never under any circumstance use more packing in a stuffing box than is absolutely necessary to keep the pump from leaking at this point.

Consult a packing engineer if in doubt as to what grade of packing the unit may require. Experimenting with packing in a pump sometimes is very costly.

The piping in most instances will require little or no attention other than caulking a few leaks that may develop, or removing clogging material which can readily be detected by the use of an ordinary steam pressure gauge. A sudden rise of the gauge when connected to the force main will indicate clogging. It is of course necessary to know the normal reading for comparison.

Check Valves

Check valves should be inspected at least once every six months, including internal parts. At this time the seats, clapper faces, and whole interior can be thoroughly cleaned. At more frequent intervals test valves for tightness. Manila paper should be used for the cover gasket after being well oiled with machine oil before installing.

The building housing the equipment must be maintained as well as the machinery. The roof must be kept in constant repair so there is no possibility of water leaking through on the electrical apparatus thereby causing untold damage. Floors should be painted and rubber matting placed thereon at points in front and rear of the switchboard to protect the operator and on the floor where traffic is the heaviest, for appearance. Walls in the dry well should be inspected and repaired when necessary to prevent any seepage of sewage or ground water.

All wood work in the entire building should be painted or varnished at least every two years to protect against dampness, also to keep the appearance of the station up to par. Costly repairs may be caused by neglecting any part of the building.

Tools

It must be understood that no person can do repair work without the proper tools. A suggested list of tools to be included along with those supplied by the pump manufacturer are:

Tool List

Socket Wrench Set (sizes 7/16" to 1⅛" inclusive).
Pliers—2 pair (1—slip joint; 1—side cutting).
Screw Drivers—set of 3 (3, 4 and 6 in. blades).
Stillson Wrenches—two (one 10" and one 18").
Hammer (machinist's, 2 pound).
Oil Cans—3 or 4 (spout oilers, plainly marked as to contents).
Putty Knife (for scraping old gaskets from pump casings).
Thickness Gauge (for spacing and setting couplings and checking clearances of pump rings).
Packing Tools—full set for removing and replacing packings in stuffing boxes).
Assorted Packings (of pump mfgr's recommendation).
Spirit Level (machinist's level of dependable make).
Fuse Puller.
Voltage Tester.

Too many so-called mechanics of the Stillson wrench type do more damage to machinery attempting an overhaul job than several years of wear and tear, to which the machine is subject. A plant of any size should have among the personnel, men capable of doing all minor and most major repairs, thereby effecting a substantial saving in a year's time over hiring outside mechanics or specialty men to come in and make these repairs.

Spare Parts

Adequate spare parts should be kept on hand at all times to replace worn out or broken parts of the equipment, thus saving time. In many cases a unit may be out of service several days waiting for some part whose initial cost may be less than $5.00. Of course, it would be practically impossible to keep enough spare parts on hand to cover the entire equipment. However, essential parts: such as holding coils for contactors likely to burn out any time, and such parts that have to be made up special at the factory, taking 10 to 30 days for delivery, should be stocked.

A most important item in the operation of a plant is the budget. No matter how well the equipment is maintained, normal wear and depreciation must be taken care of. It is false economy to repair only one part of the machine and not replace all the worn parts, just to save a few dollars temporarily.

The old cry is heard many times about effecting economy by using drastic and scientific measures which look very good on paper but in general practice are not worth a second thought, compared to the cost that is likely to be involved by delaying necessary repairs.

Value of Record Keeping

Keeping records of plant operation is an important factor. Although at the time of recording the data compiled may not seem to be of any significance, it later can be used as a reference for comparing the upkeep, electrical energy required by the different units and depreciation. An excellent method to follow is the frequent reading at stated intervals of all instruments and gauges on the units that are operating, making notations from time to time of any adjustments together with the routine work as required of an operator while on duty. Daily tabulation of all charts and logs will readily tell the story of how the plant is operating—normally or otherwise. At the end of each month the daily tabulations can be set up in the form of a monthly report, showing for example, amount of rainfall, daily pumping average, daily maximum and minimum flow, amount of screenings and grit removed, and amount of sludge removed from different tanks.

The above data can easily be transformed into a yearly report going into more detail if necessary to show the cost of pumping and treating the sewage.

In conclusion, an operator without the aid of expensive testing instruments can readily operate a plant by using some degree of intelligence and the better known common sense. His natal equipment of eyes, ears, nose and sense of touch are all invaluable aids provided, of course, that his head is something better than a hatrack.

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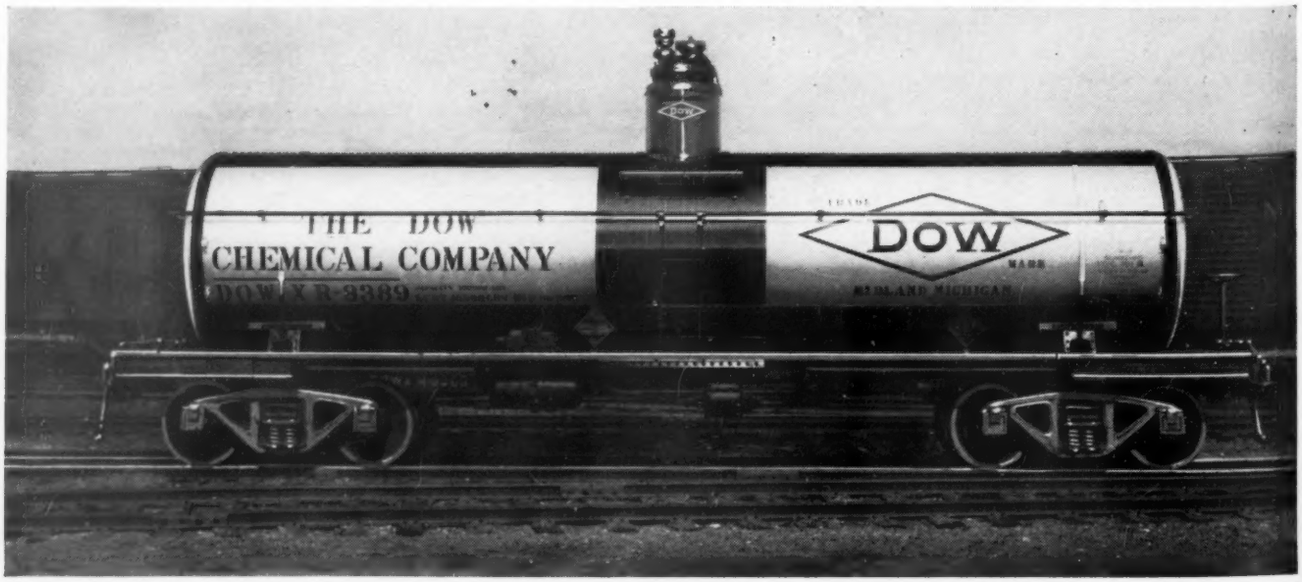
Dow Ferric Chloride 37-47% Solution is shipped in tank cars. Ferric Chloride 60% Crystals are packed in 300 lb. and 500 lb. heavy wooden barrels, permitting storage without deliquescence of the crystals.

Dow Technical Service covering design and operating problems of sewage disposal plants is available upon request to engineers.



SEWAGE TREATMENT PROCESSES
(IN BRIEF)

By A. M. RAWN
Chief Engineer and Gen'l Manager
Los Angeles County Sanitation Districts
(Associate Editor, Water Works and Sewerage)

COMMUNITY sewerage divides itself into two classifications: First, collection, and second, treatment including disposal. It is with the second that the plant operator is concerned, and it is necessary that he understand the plant's function in order that he may evaluate his own and the plant's worth. He must know what is supposed to be done and why.

There are but two general methods of ultimate disposal of sewage: one on to land for percolation into the soil, use in crop culture or evaporation; and the other into a diluting body of water. In either it is usually necessary to first do something to the sewage to change its character so that it may be finally disposed of in the manner selected or presented without nuisance or menace to health. This change is accomplished by physical, chemical or biochemical means or a combination thereof, depending upon requirements. After the sewage leaves the plant, final purification is effected by natural means invoking the same physical, chemical and bio-chemical factors which continue in the receiving waterway.

What takes place at the treatment plant depends usually upon the means afforded for final disposal. Upon rare occasions it may be unnecessary to do anything to the sewage. As a rule, however, it is necessary to reduce the load of pollution to the extent that what takes place after the sewage leaves the plant will not violate decency or constitute an invasion of private or public rights.

It is always the organic material held in suspension or solution in sewage which causes its foul odors and serves as a food supply for bacterial life. Most plant treatment is, therefore, aimed at reducting the organic load before turning the effluent over to Nature to complete the job. The plant process is, therefore, the leveler between what is afforded by Nature as sewage treatment and what overall is required.

Sewage Treatment

"Sewage Treatment" is the term descriptive of what happens to the sewage in the plant and, depending upon the type of plant, it may mean anything from bar screening to complete reclamation of a reusable supply of water from the original sewage, plus destruction of all of its organic solids.

Screening

Commencing with the simplest, which is screening, one may state that screening sewage through a bar screen (with openings one inch or greater between bars) is only slightly better than no treatment at all. It is a method usually employed to protect pumping equipment from large floating trash. Smaller openings, down to a half inch, do a slightly better job, removing some garbage and the like; while mechanical screens with fine openings, less than a quarter of an inch in width, may be expected to remove from three to ten per cent of the suspended solids, depending upon the condition of the sewage. Fine screens are useful in preventing the appearance of objectionable floating matter where disposal by dilution is effected, but otherwise have little effect upon the pollutional characeristics of the sewage.

Grit Removal

Grit chambers are tanks in which sewage is retained for one or two minutes, flowing at a velocity slightly less than one foot per second; and wherein the heavier inorganic solids such as sand, grit and the like, settle out. Though useful in protecting equipment, and guarding against the sanding up of slow-flowing outfall lines and in sludge digestion tanks, the material removed is not putrefactive and its presence or absence has no effect upon the pollutional characteristics of the sewage.

Sedimentation

Settling or subsidence tanks are built to permit the sewage to flow through at low velocities, usually about a foot per minute. The principle involved is that when the velocity of the sewage is retarded, its transporting characteristics are greatly diminished and materails heavier than water, held in suspension because of the dynamic property of the flowing stream, tend to settle to the tank bottom; while those which are lighter float to the surface. By this means from fifty to eighty per cent of suspended material may be removed from sewage by simple physical separation. This process of settling and floating and the subsequent removal of the separated particles from the fluid has a great effect upon the pollutional characteristics of the sewage. It may reduce the sewage strength as much as 30 per cent and by removing the coarser suspended and floating solids, it renders the sewage effluent, or that which flows on, far more susceptible to rapid natural purification processes than otherwise and precludes local nuisance created by sludge deposits in the water course.

Three types of settling tanks are employed in sewage treatment: (1) The flow-through chamber of an Imhoff tank which has a slot in the tank bottom through which the settleable solids drop to a digestion chamber below. (2) The settling chamber of a septic tank where the sewage is in direct contact with the digesting solids. (This type is being rapidly supplanted by others.) (3) The rectangular or circular tank equipped with mechanical skimmer and bottom ploughs from which settled material is withdrawn from time to time or continuously, while the floating material is skimmed automatically or otherwise. The end results are similar in all three: certain of the suspended solids are removed and the degree of purification effected in considered primary treatment.

An understanding of the simple principles of subsidence and floating should enable the operator to comprehend that any disturbance in the contents of a subsidence tank will cause suspended particles to leave the tank with the effluent. Such disturbances occur when short-circuiting takes place; if sludge lies so long in the tank that it ferments and tends to float (this is the great disadvantage of the septic tank); when grease becomes thick upon the surface and appears on the downstream side of the baffles; or when the tank is overloaded to the extent that velocities are greater than those for which it was designed. Plain subsidence, or settling, is an expensive natural process of physical separation, but end results may be greatly affected by a lack of care in operation.

Chemical Precipitation

In some instances it is considered advisable to increase the removal of suspended solids and to remove by adding chemicals, usually in the form of iron salts and lime, then gently stirring or agitating to build up a floc which, being slightly heavier than water, will settle out if the sewage velocity is stilled to ordinary subsidence tank velocities. Treated with chemicals in the proper quantities and correctly flocculated, the effect of such a process upon the pollutional characteristics of sewage is very great. The sewage is reduced in strength more than 60 per cent and a plant effluent may be produced which is clear, low in suspended solids, and in such condition that the natural processes which will complete the reduction of its organic solids, can do the job readily. There is nothing mysterious about the process, although the changing character of the sewage may influence its effectiveness from time to time. Accurate observations and proper tests will lead the operator to a practical knowledge of these changes and in time permit him to readjust operating conditions to meet them.

Mechanical Filtration

Rapid mechanical filtration of effluent from settling tanks is gaining popularity and appears to be an excellent means for the removal of pollutional load. Filtration through "Magnetite" is the best example of this process. In it the sewage flows through a bed of "Magnetite" grains which filter out the suspended solids and are periodically cleansed by a magnet which, passing over the grains, disturbs them, loosening and removing the suspended matter caught in their interstices. This type of plant produces an excellent effluent and the filtration process has a far-reaching effect upon the pollutional characteristics of the sewage, reducing its strength by 50 per cent to 60 per cent. The reduction in filterable solids is to some extent proportional to the load applied.

Continuously cleaned mechanical sand filters are also being employed for the same duty.

Slow Sand Filtration

Intermittent sand filters follow plain settling tanks in some instances. Some are no more than diked areas in nearby drainage courses, while others are elaborately built up and underdrained. In the former the sewage water soaks into the soil, reaching underground waters, while in the latter it is collected after passing the filter and led to final disposal at the selected site. In the under-drained bed, usually 3 to 5 ft. in thickness, the lower strata are of coarse rock. From these there is a graduation in size to fine sand at the surface. Effluent from the tank flows through the bed, losing its suspended load and undergoing a measure of oxidation. Beds, operated intermittently, are allowed to rest for about twice the period of operation. Settling, plus intermittent sand filtration, has a very great effect upon the pollutional characteristics of sewage, reducing its strength in excess of 95 per cent and producing a clear, inodorous, stable effluent which may be disposed of without possibility of trouble. Unfortunately it is not adaptable to large installations because of the great area required. A hundred thousand gallons per acre per day is an average rate of dosing.

Trickling Filters

Another contrivance frequently used to treat settling tank effluent is the trickling of sprinkling filter. It is an underdrained bed of fairly coarse rock upon which the partly clarified effluent from the settling tank is sprayed or sprinkled. It is in reality a decolloidizing and bacteria bed, the oxidizing bacteria living in slime which coats the rocks. As the sewage passes over the slime a goodly part of its organic solids are extracted and oxidized. It has a great effect upon the pollutional characteristics of the sewage, reducing them more than 80 per cent, particularly if followed by secondary settling chambers in which dislodged particles of slime may settle out.

This is a fine rugged process which if correctly operated does an excellent job of purification. It will stand shocks of overloading better than most any other type of oxidizing process. It can, however, be abused; overloading with too great a solids component for long periods will destroy the efficiency of the bacteria in the slime and adversely affect the effluent. Ponding, with its resulting uneven distribution, should be avoided. The underdrains must be kept clean, filter flies controlled, and sprinklers regulated to dose evenly. Chlorine scientifically applied is of great assistanse in relieving ponding and reducing filter flies.

The so-called High-Rate Trickling Filter is a new development in which the sewage is continuously sprayed over the bed at rates of 10 m.g.d./acre and upwards. The trickling filter thus operated produces effects akin to the activated sludge process in its pre-vitrifying stages. The degree of purification is 70 per cent or better.

The Activated Sludge Process

The activated sludge process is the most intricate, does its best job on large quantities of sewage, costs the most, and presents the greatest and most perplexing problems. It usually follows plain subsidence. In this process bacteria densely populating a suspended floc are poured into settling tank, or fine-screen, effluent and the mixed liquor aerated with one or more cubic feet of air per gallon of mixed liquor, for from four to six hours. From the aeration stage the mixed liquor flows into settling tanks, where it remains fairly quiescent for thirty minutes to an hour during which the floc settles to the tank bottom and is removed in the same manner as settled solids in a primary subsidence tank. The effluent runs on to disposal, while the activated sludge is reconditioned and re-used. Of all the known processes commonly used, this is the most effective in reducing the pollutional characteristics of sewage. It is equally applicable to large or small quantities and lends itself to the design of a compact plant in a relatively small area. In effectiveness it attains an efficiency at times exceeding 95 per cent, and ordinarily reaches well over 90 per cent. It is the process best likely to create odor nuisance, other than the chemical precipitation process.

The biochemical principles involved are quite similar to those of the trickling filter except that in the case of activated sludge, the sludge (slime) is taken to the sewage and aerated with the sewage rather than the sewage being taken to the aerated slime covering the stones. It is impossible to state the case for activated sludge simply; it is complex, and success in operation usually depends upon accurate laboratory control and intelligent observation as well as mechanical knowledge.

Effluent Polishing

Occasionally an oxidizing process such as the trickling filter or activated sludge will be followed by rapid mechanical filtration. Filtration of an oxidized effluent produces about the best that sewage treatment affords, particularly when the filter effluent is chlorinated. Such effluent is usually well adapted to agricultural and industrial needs and may be disposed of most any place without invasion of the rights of others. For the purpose magnetite, sand and vacuum drum filters have been employed.

A number of variations of the foregoing processes are currently used in this country, but all of them employ in some form screening, subsidence, filtration, oxidation, and/or chlorination alone or in combination, as basic treatment. Final disposal is into the sea; into flowing streams where available; by irrigation for crop culture, or percolation into the underground waters.

Sludge Disposal

So far this discussion has been about the character of plant effluents. Follows a brief description of means employed in disposal of sewage solids (sludge) retained at the treatment works:

Bar screens may remove from 20 to 100 lbs. of trash per million gallons of sewage, depending upon the bar openings. Disposal of this is usually by incineration or burial. With fine screens having a 16th-inch clear opening, 100 to 300 lbs. of dry solids per million gallons may be removed. Disposal is usually by incineration or burial where screening is the only treatment; but where further treatment is employed as subsidence or activated sludge, the screenings are frequently comminuted and returned to the sewage flow to be disposed of with the other suspended solids.

Plain subsidence without the aid of coagulation may remove from ordinary city sewage, 1,000 to 1,500 pounds of suspended solids per million gallons. This material is digested in the septic or Imhoff tank; or, through most modern practice, in separate tanks. If digested, the sludge is rendered non-putrescible and inoffensive and may be disposed of for fertilizer or used for filling low-lying areas. If, however, it is not digested, it must be heat-dried before use as a fertilizer or else incinerated. Activated sludge may be digested in the same manner as primary sludge or may be filtered and heat-dried and disposed of as a fertilizer. The digestion of bar or fine screenings (uncomminuted) has not proven economical.

On the whole, sludge digestion has remained more popular as a means of sewage solids disposal than drying or incineration of the raw solids. It appears to be much less expensive and produces valuable end-products in the form of combustible gas and low-grade fertilizer. Digestion may be accomplished without odors despite the fact that the residue is air-dried. Sixty to 120 days in an Imhoff or septic tank, and less than thirty days in a controlled (heated) separate sludge digestion tank, is considered sufficient.

The digested sludge is dewatered in two ways. (1) On sand, drainage and drying beds. (In the more humid sections and where long gray winters are experienced the drainage beds are covered with glass enclosures.) (2) On rotary type vacuum filters, the sludge cake being heat dried and used as a soil improver are incinerated. In some instances the wet filter cake is hauled out on the land from the filter.

In dewatering a vacuum filter the sludge is clotted by chemicals to release the free water and markedly increase the capacity of the filters, in addition producing a cake of much lower moisture content. The most successful user of the vacuum filter has been in conjunction with partial if not complete digestion of the solids. Thus the valuable power producing digester gas is recovered and put to use in paying a good slice of operating costs.

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SEWAGE TREATMENT PLANT OPERATION

Compiled from Various Sources

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A DAILY inspection of each major unit of the plant by the plant operator should be made, any unusual conditions recorded, and faulty conditions immediately remedied. The plant operating data should be fully compiled each day, and kept, as an aid in maintaining the plant in proper operating condition. Such records are valuable for future reference and as evidence.

It is especially important that the daily flow or rate of flow of sewage reaching the plant be measured and recorded. Methods commonly employed to determine sewage flow are as follows:

1. Weir measurements.
2. Counters on dosing tanks of known capacity.
3. Capacity of pumps and period of operation.
4. Recording meters (Venturi, weir, etc.).
5. Dosing tank period for filling.

Records of power consumption and supplies, tools or chemicals obtained should be maintained. A daily log book for keeping such records and information concerning general or unusual conditions is very useful.

The air temperature, wind direction and general weather conditions should be recorded daily. This information is valuable in the investigation of nuisance complaints such as odors.

It is also essential that a few simple tests be made to determine the efficiency of separate units of the plant or of the plant as a whole. The results of these tests and a record on operation will:

1. Indicate to the operator whether the plant is or is not functioning properly.
2. Aid the municipality or institution in case of law suits resulting from alleged pollution or nuisance.
3. Assist consulting engineers in planning changes or additions to the plant.
4. Enable the officials responsible for the operation of the sewage disposal plant to prepare reports to the public and to the State Department of Health on the operation and efficiency of the plant.

The operator should have for ready reference plans or blue print designs of the plant, showing the dimensions of each unit and all pipes, valves, gates, etc., in order that he may be able to fully understand the construction and operating details of the plant.

A competent sanitary engineer can materially improve operating conditions through guidance and advice. It would be advisable for municipal or other officials to retain consulting engineers, or an experienced operator from a nearby plant, for a few years after completion of a new plant in order to supervise plant operation. Operating difficulties may frequently be prevented or readily corrected by following their advice.

Operators of sewage treatment plants should always remember that sewage gases are combustible and also explosive under certain conditions. Such gases may be toxic and asphyxiating. It is, therefore, necessary to take unusual precautions where such gas may be present either in the sewer system or at the treatment plant. No open flames or other sources of ignition should be permitted. Adequate ventilation of manholes and other similar enclosures before entering is always advisable. Moreover, no one should ever enter a place where such gases are likely to be present without an emergency rope attached to his person and two watchful attendants stationed outside. When the gases are toxis, i. e., containing poisonous gases, a special gas mask should also be used.

The following are a few fundamental details of the proper operation of sewage treatment plants. Local conditions may alter somewhat the following operating details but in general these notes give a resume of the operating procedure for the various types of treatment described.

Grit Chambers

1. Grit chambers should be cleaned after every large storm.
2. Grit chambers should be cleaned whenever tests show that the grit compartment (the compartment below the inverts of entering and outlet channels) is filled with hard material to 50 or 60 per cent of its capacity.
3. The grit should be promptly disposed of by burying it or drying it on sludge beds. If it is sufficiently clean, it may be used for filling in low land.

Coarse Screens (1/2-Inch to 3-Inch Openings)

Screenings, unless properly disposed of, are frequently a serious source of nuisance at a treatment plant because they decompose readily, giving off obnoxious odors. They will also encourage the breeding of rats and flies unless properly cared for. Furthermore they are unsightly and repulsive to visitors.

1. Remove the screenings twice daily or oftener if necessary to prevent clogging of the screen and consequent backing up of sewage in the outfall sewer.
2. Promptly dispose of screenings by:
   (a) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with borax, chloride of lime, or other disinfectant and covered with earth as early as possible.
   (b) Incineration where possible.
   (c) Grinding, either returning ground material to the sewage flow or mixing it with the primary tank sludge going into digesters.
3. Clean the screen chamber, removing all accumulated sludge and grease, at least once a day.

Fine Screens (1/2-Inch or Less)

1. Fine screens are usually continuously mechanically cleaned, either by water, air or revolving brushes, and therefore all moving parts should be properly lubricated to keep them in proper working condition.
2. Remove and dispose of screenings promptly by:
   (a) Mixing with garbage and incinerated.
   (b) Dewatering by pressing, and then incinerating or burying the solids.
   (c) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with chloride of lime, or other disinfectant, and covered with earth as early as possible.
   (d) Digested with other solids removed by sedimentation.

Septic Tanks

1. Sludge and scum should be removed whenever they accumulate to a combined depth equal to 1/4 the depth of the tank below the flow line.
2. Sludge should be removed when large suspended particles are observed in the effluent, or when the daily test of settleable solids in the Imhoff cones shows any appreciable increase of settleable solids in the effluent.
3. All inlet and outlet channels, pipes, weirs, valves, etc., should be kept clean and free from accumulations of grease and grit.

Mechanically Cleaned and Plain Settling Tanks with Separate Sludge Digestion

(A) Plain Settling Tanks:

1. The settled solids should be completely removed at frequent intervals, at least twice daily, from the settling tanks to the separate sludge digestion tanks. Mechanical equipment installed for the collection of sludge should be operated for a sufficient length of time before drawing sludge to insure complete removal of the deposited solids.
2. Septic action in the plain settling tanks as evidenced by "gassing" or rising sludge or an appreciable increase of settleable solids in the settling tank effluent should be avoided by prompt and regular removal of sludge to the digestion tanks.

3. Grease and scum should be removed at least daily, using the mechanical skimming device or by using a perforated hand-skimmer and the tanks should be maintained in a clean appearing condition at all times.

(B) Separate Sludge Digestion Tanks:

1. The contents of single tanks should be stirred or agitated at intervals by recirculation or other means to assure proper "seeding" of the fresh solids and to afford rapid and efficient digestion. Such stirring also lessens the chance of acid production, "foaming" difficulties, and excessive scum formation. Where there is surplus capacity or stage digestion this operation is of doubtful benefit.
2. Where heating coils or other adequate means of heating the contents are available, the temperature should be maintained at about 85° F.
3. The amount of fresh solids added daily should not be over one twentieth (5%) of the amount of "ripe" sludge in the tank, on the basis of the dry solid content of each.
4. Care must be used in removing digested sludge to avoid the removal of such a large amount that the ratio of "ripe" sludge to fresh sludge added drops below twenty to one.
5. By concentration tanks or otherwise the solids content of the sludge added to digesters should be as high as is practical to avoid loading the digesters with liquid which reduces the time of the solids in the digesters, creates undue disturbance and chills the contents. This matter is far more important than is generally realized.

Imhoff Tanks

1. Sedimentation Compartment:

(a) Grease and scum in the sedimentation compartment should be removed daily. This is best accomplished where no mechanical means is provided, by the use of a dish-shaped perforated skimmer. Such grease and scum should be promptly disposed of by burying or burning. Where objectionable conditions are not likely to develop, the grease and scum may be placed in the gas vents.

(b) The sides and slopes of the sedimentation compartment should be carefully scraped with a rubber squeegee and all solids pushed down through the slots at least twice a week.

(c) The slot in the bottom of the sedimentation compartment must be kept open and free from obstruction of any kind. At least once a week the slot should be cleaned by the use of a heavy chain drag, taking care to traverse the entire length of the slot.

(d) Failure to carefully follow the foregoing operating procedure will usually result in an effluent of inferior quality and where a trickling filter is used there will be deposits and accumulation of solid material on or in such filter, due to grease, scum or sludge being carried through the tank.

(e) Where the design of the tank will permit, the direction of flow through the sedimentation compartment should be reversed at least once a month, in order to distribute the solids uniformly in the digestion or sludge compartment.

2. Gas Vents or Scum Compartment:

The scum in the gas vent should be broken up at least weekly to afford an easy escape for the gas from the digestion or sludge compartment. Control of the scum may be accomplished by some of the following treatments:

(a) Breaking the scum up with a hoe, rake, or other suitable tool.

(b) Hosing the scum in the gas vents with water under pressure.

(c) Punching holes through the scum at two-foot intervals with a wooden pole.

(d) The scum may be removed and dried in a sludge drying bed if its depth approaches 2 to 3 feet in the vents. Usually it burns readily and if incinerated may create a hazardous flash, due to grease content.

(e) Treatment of the scum in the gas vents daily with hydrated lime at a rate of about 10 lbs. per 1,000 population has been found to be helpful in controlling excessive scum formation and to aid in maintaining the pH value of the digesting sludge.

3. Sludge Compartment:

(a) The height of the sludge in the sludge compartment should be determined at inlet and outlet ends of the tank at least once a month. The use of a pump for this purpose is the most desirable and satisfactory. The use of the plate or disc method is not usually satisfactory. The following are suitable methods for measuring the depth of sludge:

(1) One method involves the use of a pitcher pump provided with a rubber suction hose, weighted on the end and the length marked on the hose at intervals of 2 feet, measuring from the weighted end toward the pump. The hose is gradually lowered through the slot in the sedimentation compartment, meanwhile constantly pumping, and the length of immersed hose, when sludge first comes through the pump is determined. When the sludge elevation is reached, the pump will usually "choke" before sludge appears.

(2) The sludge depth may also be determined by use of an iron plate or weighted wooden block, about 12-18 inches square, attached to a wire or chain lowered through the gas vent. The plate or block will stop when the sludge is reached and the distance from the surface to the sludge level is determined from the graduated wire or chain by which the device is lowered. The pump method is by far the most positive procedure.

(b) Sludge should be removed:

(1) Whenever the sludge depth approaches within 18 inches of the slot in the sedimentation compartment.

(2) In small amounts at frequent intervals rather than in large amounts at longer intervals. Usually some sludge should be drawn every month.

(c) Sludge should be removed at a slow regular rate to avoid the formation of a channel through the sludge in the sludge compartment and the withdrawing of partially digested sludge or the liquid above the sludge.

(d) If sludge does not flow readily, it may be started by:

(1) Agitating with water under pressure through perforated water pipes in the bottom of the sludge compartment, if such pipes are available.

(2) Applying water pressure through hose immersed into the sludge compartment or through the sludge riser pipe.

(3) Agitating around sludge inlet with long rods through the sludge riser pipe.

(e) Avoid withdrawal of all the sludge from the tank. Leave sufficient digesting or "seed" sludge to prevent the difficulties incidental to starting a new or completely cleaned tank. Usually not over half the depth of sludge in the tank should be removed at any one time.

(f) After use the sludge pipes should be flushed out and refilled with water or sewage to prevent the sludge from hardening and clogging the sludge pipes.

4. "Foaming:"

There are a number of possible causes for "foaming" such as industrial wastes like milk or cannery wastes, "mash" or "wine" wastes, drawing out too much sludge at one time, or increased temperatures in the sludge compartment. Foaming is almost invariably associated with an "acid" condition of the sludge and in such cases may be minimized or corrected by treatment to counteract the acidity. However, there is such a thing as alkaline foaming but it is not common.

When foaming occurs, there are a few simple treatments which may under certain conditions remedy or improve the condition.

(a) Relief may sometimes be obtained by drawing some sludge.

(b) Hosing the gas vent area with water under pressure will sometimes help.

(c) Cutting the tank out of service if possible and allowing it to rest will permanently improve conditions.

(d) Paddling the foam with long-handled hoes is also temporarily effective.

(e) Hydrated lime added through the gas vents at daily intervals will frequently correct a foaming condition.

(f) Treatment of the raw sewage with chlorine at rates of 20 to 50 pounds per million gallons will often bring foaming under control.

Trickling or Sprinkling Filters

1. The nozzles should be inspected daily. All clogged nozzles should be cleaned and any broken nozzles replaced.
2. The surface of the filter bed should be kept free from plant growths.
3. The formation of ponds or "pooling" on the surface of the

filter bed may be remedied or prevented by:
(a) Flushing the surface of the filter with a fire hose.
(b) Raking or forking the surface of the filter bed.
(c) Punching holes through the top layer of the filter medium with iron bars.
(d) Heavy applications of chlorine, chlorinated lime or other chemicals for short periods applied directly to the bed surface or in the filter bed influent at the dosing tanks. The treatment is usually most effective and economical if applied to the low night flows of weak sewage.
(e) Operation of units may sometimes be improved by cutting them out of service occasionally for a period of 12-48 hours.

4. Where the design of the filter bed will permit, the presence of large numbers of filter flies may be controlled by periodic flooding of the filter beds. Chlorine application, as for ponding, is also very helpful but not a 100% effective remedy. In flooding the sewage it should be chlorinated to delay oxygen depletion and septic action during the holding period.
5. The distribution piping should be flushed periodically.
6. The underdrains should be flushed out occasionally with water hose or other suitable flushing devices, if the filters are so constructed as to make this possible.
7. Where revolving distributors are installed, frequent inspection of water or mercury seals should be made.
8. Where revolving distributors are installed, the flow from the nozzles should be adjusted so that the flow delivered is proportional to the area covered, i. e., the end nozzle should deliver twice as much as the one half-way out from the center. The center nozzles should deliver very little flow—only thin share for the ratio of area covered.

Secondary or Final Settling Tanks

1. The sludge should be removed frequently to prevent septic action and gasification of the solids which results in discharge of solids with the final effluent. This cleaning is usually necessary at least once a month, or oftener, during the summer season.
2. The depth of the sludge should be determined at frequent intervals by the use of a sludge sounder or other device.
3. The sludge may be disposed of in the same manner as sludge from primary settling tanks, i. e., pumped into primary settling tanks or into separate sludge digestion tanks direct for digestion. In the latter case density of the sludge is an important consideration to perclude the effects of dilution on the digesters.

Sludge Drying Beds

1. Sludge beds should not be filled to a depth of more than 12 inches or to such a depth that the sludge cake cannot be removed within two weeks in good drying weather.
2. The surface of the drying bed should be kept clean and free from all previously discharged sludge. *Never discharge wet sludge upon dried or partially dried sludge.*
3. The surface of the sludge drying beds should be kept nearly level to afford an even distribution of sludge over the surface of the bed.
4. Dried sludge may be used for fill, buried, or spread upon the ground, where it will not be carried into a stream or watercourse by rain.
5. In many communities the sludge is readily disposed of by giving or selling it to nearby farmers for use as fertilizer. This should be encouraged as sewage sludge has been found to have fertility and soil improving values. It is not advisable, however, to use it for the fertilization of crops which are served in an uncooked condition. For best results the sludge cake should be shredded or pulverized before attempting its sale.

Sand Filters

1. The beds should not be used continuously but sufficient time should be allowed between doses for the bed to drain thoroughly and "rest" between applications. Satisfactory operation of a filter bed depends on the presence of oxygen in the bed and therefore opportunity for the entrance of air into the bed must be provided by the "rest" periods.
2. The beds should be periodically cut out of service, allowed to dry and the surface raked or scraped clean.
3. "Pooling" should not be allowed to develop on the beds as this tends to produce septic action, obnoxious odors and an effluent of poor quality. Pooling indicates that cleaning is necessary. Frequently a harrowing is all that is required. Eventually skimming will be required.
4. The surface of the beds should be kept level to afford uniform distribution of the sewage.
5. Weeds, grass, etc., should not be allowed to grow on the beds.
6. The depth of the bed should be maintained by removing during cleaning only the least possible amount of sand. Once a year clean sand should be added to replace that removed during the year.
7. Where natural sand percolation beds are used it is sometimes advisable to shallow harrow the beds after careful removal of all organic deposits.

Chlorination

The purpose of chlorination is to prevent bacterial contamination of streams or other bodies of water, used for municipal or industrial water supplies, irrigation, shell-fish growing, recreation or bathing.

The effective chlorination of sewage or sewage effluents depends upon the presence of adequate quantities of chlorine at *all* times in all portions of the sewage for sufficient time to provide the necessary period of contact between the disinfectant and the bacteria in order that disinfection may be efficient.

The strength of any sewage varies greatly with seasonal changes, with the days of the week and during the hours of the day. The amount of chlorine required varies accordingly.

1. Chlorine should be applied in such quantity that there will be a residual of at least 0.5 p.p.m., as determined by the ortho tolidine test, after 15 minutes contact of chlorine with the sewage or the effluent, depending upon whether pre- or post-chlorination is practiced.
2. The test for residual chlorine should always be made at the time when the sewage or effluent is the strongest or when it requires the largest amount of chlorine for treatment.
3. Weigh chlorine tank each day at the same time to determine the amount of chlorine used during the preceding 24-hour period.
4. The chlorine must be applied *continuously* in the proper quantities.
5. Before connecting a new chlorine cylinder to the control apparatus, blow off some of the chlorine from the new cylinder into the air in order to prevent clogging of the apparatus. Store the empty cylinders apart from the full ones so as to avoid mistaking empty cylinders for full ones.
6. Examine the chlorine apparatus daily and if any trouble is found which cannot be corrected by the operator, notify your superior at once.
7. It is not advisable to draw chlorine from any one cylinder at rates higher than 40 lbs. of chlorine in a 24-hour period, because of the danger of "freezing" and slowing up the chlorine flow. If more chlorine is necessary, two or more containers should be connected and used in parallel.
8. The operator should always have on hand a stock of the usual replaceable parts for the chlorine apparatus and a reserve supply of chlorine cylinders.
9. Leaks in the chlorine apparatus should be promptly repaired to prevent corrosion of the equipment and structures. Such leaks may be detected by the formation of white fumes when tested in the immediate vicinity with the vapors from an ammonia solution. (Household ammonia is satisfactory).
10. During cold weather heating facilities should be provided to maintain a temperature of 60° F. and never less than 50° F., in order to prevent so-called "freezing" in the chlorinator and stoppage of the chlorine flow. It is frequently necesssary to heat the water supply to the tray of the chlorinator to prevent "chlorine-ice" formation.
11. Chlorine is a liquid when under pressure in the cylinders and is an irritating gas which is heavier than air when released. It may produce serious after effects if inhaled. A satisfactory gas mask should be available at all plants where chlorine is handled.

Activated Sludge Tanks

1. Sludge percentage tests (settling for ½ hour a liter graduate) should be run twice daily on the mixed liquor of the aeration tanks, sampled at the half-way point.
2. When the sludge percentage of the mixed liquor exceeds 30% (300 c.c. in the liter graduate), sludge should be withdrawn. Some plants have been found by experience to operate more efficiently at a lower per cent.
3. Excess sludge should be wasted into the raw sewage if primary sedimentation is practiced or wasted directly to digesters or via thickener tanks if these are provided. Such tanks are an important adjunct to the functioning of digesters.
4. Direct drying of untreated sludge results in odor and fly nuisance.
5. For small plants, dissolved oxygen tests on the effluent

from samples taken from the clarifiers should be run daily. B. O. D. and suspended solids tests on the effluent should be run at least twice weekly.

6. Cracked or leaking air diffusion plates should be watched for and quickly repaired.
7. Air and sewage regulating valves should be operated at least once a month to insure against sticking.
8. Bulking is said to occur when unusual amounts of suspended solids pass out with the effluent. It may sometimes be controlled by one of the following practices:
   (a) Increasing the supplied air or reducing the solids carried in the aeration units.
   (b) Continuously adding lime sufficient to bring the pH up to 9.0 (for small plants).
   (c) Adding small amounts of fine clay (for small plants).
   (d) Moderate chlorination of the returned sludge.
   (e) Bypassing the sewage until condition is corrected.
   (f) Eliminating industrial wastes from the sewerage system when these are proven to be causative.

If bulking becomes a chronic problem, the administrative authority should be fully informed and an investigation by a competent sanitary engineer recommended.

9. Air pressure on this diffuser manifold should be recorded regularly, as increase in pressure results in increased power cost.
10. Operation of final settling tanks is similar to operation of primary settling tanks.

Neatness, Cleanliness, Beautification

1. It is very easy for a sewage plant operator to become negligent. The appearance of his plant reflects in most cases his own character.

2. A limited planting of shrubs and trees will add greatly to the appearance of a plant. Most administrative authorities, if properly approached, will provide at least in a small way, for this improvement. Select hardy plants which require a minimum of attention.

3. Paint is an investment. A plant where painting is neglected will soon require expensive replacements. Learn all you can about paint; many conditions require special paint.

4. A set of neat, well-kept records is a convincing argument when an operator is asking for improvements.

5. A clean plant is usually a well-run plant.

6. An untidy plant is a hazard to life and limb. Slippery steps, unused equipment left in the way, can be the cause of a nasty fall.

7. Work around sewage is always subject to health hazard; extra care and cleanliness are, therefore, essential. A first-aid kit should be on hand and used for even minor injuries. Arrange for prompt medical service for more serious accidents.

8. Make a study of the life cycle of flies and mosquitoes. A knowledge of this subject will enable an operator to control with a little thought and effort, most insect nuisances.

Last but Not Least

9. Join and take an active part in your local sewage works association. The journals and the exchange of operating experience with other members is a rich source of progressive ideas.

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CONTROL OF ACTIVATED SLUDGE BULKING*

By E. E. SMITH,

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The operation of the Activated Sludge type of sewage treatment plant has the ever present danger of the so-called sludge bulking. Sewage literature abounds with descriptions, reasons for and treatment of this phenomenon. Experiences at the Lima Sewage Treatment Works seems to indicate close correlation between a marked increase in the numbers of bacterial filaments in the aeration units and poor settling of sludge in the final settling tanks, decrease in dissolved oxygen in final tanks, and poor clarification of final effluent. Sludge bulking seems to be the common cause of inefficient and uneconomical operation of activated sludge plants.

During the summer of 1934 when sludge bulking occurred, all previously described remedies were employed. The sewage upon which these remedies were tried was, in common to most sewages of that drought period, unusually strong and high in temperature, with the consequent necessity of efficient purification during the low stream flows.

Experimentation with Chlorine

Sanitary Engineer J. K. Hoskins of the United States Public Health Service had mentioned to the writer some beneficial results to the process following the use of chlorine at the Stream Pollution Investigations Experimental Plant, in Cincinnati. It was decided, therefore, to look into the effects of chlorine gas on the returned activated sludge.

The design of the Lima Sewage Treatment Works was admirably adapted for this particular experiment for the following reasons:

Activated sludge from the final tanks is brought through two separate 12 inch sludge lines from the tank sumps to a sight feed hopper where separate sludge valves control the sludge flow into a 14 inch combined gravity line conveying the sludge 95 ft. to the returned sludge sump. For purposes of chlorination this arrangement permits *good mixing* and a contact period of ten to twenty minutes, depending on the rate of sludge returned. The results obtained from the use of one tank of chlorine, applied without careful control, were so evidently desirable, that arrangements were made for use of W. & T. solution feed chlorinator.

Observations during the treatment of the returned sludge revealed that seven days after the start of chlorination filaments were absent from the sludge. The ratio of *p.p.m. chlorine to each per cent of solids in the returned sludge* is apparently a governing factor in the action of filament removal, because results were not being obtained when that ratio was below 1.00 during the second application of chlorine. No filament removal was noted for the twelve days of low ratio chlorine dosage.

Inasmuch as the last eleven days of application of chlorine during the first experiment and the first twelve days of the second experiment seemed to indicate that chlorine applied below the apparent threshold ratio of 1.00 was without sufficient effect, a further experiment with chlorine was made at ratios of 2.00 or more.

At the Lima Sewage Treatment Works daily microscopical examinations of the aeration tank effluent are made, as well as the usual hourly estimations of percentage of settling solids in the aeration tank effluent. From the indications of these two determinations the chlorine produced a marked reduction of the excessive numbers of filaments.

Economy of the Process

Air requirements have been reduced to little more than the delivery of the smallest size blower, without regard to variations in sewage flow. It may be estimated that air requirements, without the danger of bulking, should not exceed an average of 0.90 cu. ft. per gallon of sewage. As bulking could be expected usually when the air-sewage ratio was reduced below 1.00 to 1.25 cu. ft. per gallon, the ability to use chlorine as above indicated resulted in a net saving.

The application of air has been as low as 0.62 cu. ft. per gal. daily average and as low as 0.78 monthly average during chlorination. Without the ability to correct sludge bulking so readily and effectively with chlorine such low applications of air would have been unwise and impracticable.

[*Excerpts from an article which appeared in WATER WORKS AND SEWERAGE, October, 1935, here reproduced because other plants have subsequently found the Lima scheme of mild chlorination of returned sludge beneficial in holding oxygen in the aeration units and maintaining performance of the activated sludge process on a more even keel in difficult operating periods.]

INNIS, SPEIDEN & COMPANY

117 Liberty Street NEW YORK, N. Y.

Chicago Cleveland Boston Philadelphia Gloversville, N. Y.

Ferri-Clor AS A COAGULANT FOR SEWAGE AND INDUSTRIAL WASTES

The chemical treatment of sewage and industrial wastes is an effective and economical method of increasing the efficiency of the ordinary sedimentation plants. Such treatment requires but little plant construction or capital investment. It provides a high overload capacity and flexibility in proportioning to produce the degree of purification required. Seasonal loads are readily handled with the Ferric Chloride treatment.

Ferric Chloride coagulates sewage and industrial wastes, thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

Experience has shown that Ferric Chloride is also an *ecomonical* coagulant for sewage and wide range of industrial wastes.

FOR COAGULATING SEWAGE

Ferric Chloride provides an inexpensive and efficient method of dealing with plant overloads, and reduces original plant investment by increasing the capacity of the sedimentation plant.

Amount of Ferri-Clor to Be Used

The accepted procedure in determining the dose of Ferric Chloride required to coagulate a given sewage is to set up "jar tests" with sewage to be tested. 2 qt. Mason Jars and stock solutions of Ferric Chloride and Lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several Mason Jars. Add to the sewage in each jar, successively larger doses of Ferric Chloride stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outlined for Ferric Chloride. The amount in lbs. of Ferric Chloride or Lime required equals the number of c.c. used in the selected test × 10 × total sewage flow (m.g.d.) × 8.33.

FOR SLUDGE CONDITIONING

Ferric Chloride is accepted as the agent most efficient from the standpoint of performance and cost for the coagulation of sludge prior to its dewatering in the filter.

Amount of Ferric Chloride to Be Used

Using the Buchner Funnel Test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. 2 to 3 minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held as in batch-mixing.

Various combinations of Ferric Chloride and Lime should be tested until the relative quantities for optimum operation are determined.

FERRIC CHLORIDE

The approximate quantities of chemical to be used in the plant can be determined from the laboratory tests, provided, of course, that the same strength chemicals are used in the plant. The quantity of Ferric Chloride solution in gallons per 1000 gallons of sludge will be 5 times the c.c. used per 200 c.c. of sludge in the test. Likewise, the quantity of Lime in pounds per 1000 gallons of sludge will be 42 times the grams used per 200 c.c. of sludge.

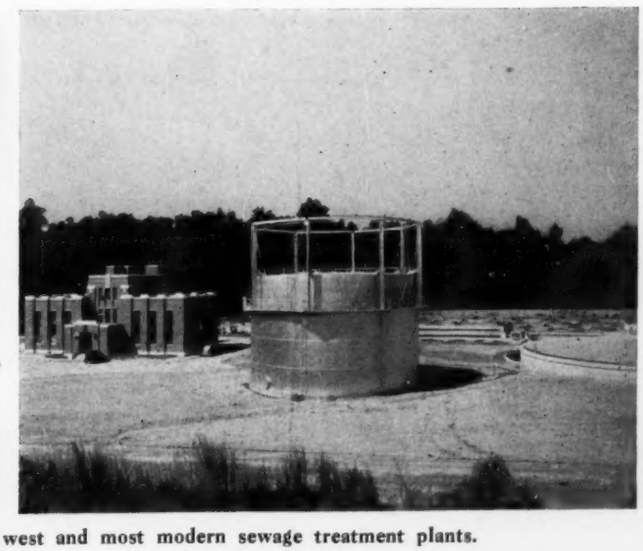
PREPARATION OF FERRIC CHLORIDE SOLUTION

The main difficulty in dissolving Ferric Chloride arises from the fact that the saturated solution is heavier than water. This means that the liquid in a simple container may have a layer of pure water at the top, even with undissolved crystals at the bottom. To overcome this difficulty, three methods have been developed.

1. Automatic gravity circulation by placing the salt on a wooden grid elevated or suspended one-half way in the tank.
2. Mechanical mixing by (a) stirring, (b) by air agitation, and (c) liquid recirculation.
3. Melting: Ferric Chloride melts at 98.6 to 102.2°F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

Ferri-Clor 60% ($FeCl_3$)

is ISCO's registered name for Ferric Chloride developed and manufactured especially for Sewage and Water Treatment use.



ISCO Ferric Chloride is used in America's newest and most modern sewage treatment plants.

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45 Riverdale Avenue
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Branches at Boston, New York, Philadelphia, Detroit, Chicago, Atlanta, Dallas, and San Francisco

Portable Gasoline Engine Driven Units
Electric Plants **Ventilating Blowers**
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HOMELITE PORTABLE ELECTRIC PLANTS
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Rugged, light-weight generators—sturdy, air-cooled gasoline engines. . . . A single, combined power and generating unit easily carried by hand and entirely independent of any outside power source. . . . Broken power lines, driving wind and rain, snow, sleet or bitter cold—Homelite gives easy starting, reliable service *at the point* where electric power is needed. . . . Emergency floodlights without delay, power for electric tools, night construction lighting—all on tap for short periods or for continuous operation. . . . Homelite can be set up anywhere a man can go—light and power *when* you need it and *where* you need it. . . . Automatic voltage control, hours of continuous operation on a gallon of gasoline.

120 Volt Direct Current Models

Model B	500 watt	total weight 61 pounds
Model S	650 watt	total weight 71 pounds
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Model HR	1800 watt	total weight 82 pounds
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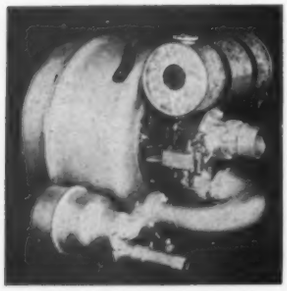
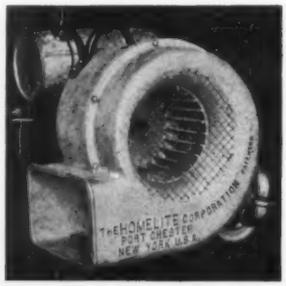
All weights include built-in Homelite gasoline engine.
Alternating Current Models available in same range of sizes.

HOMELITE PORTABLE BLOWERS for Ventilating Manholes, Sewers, Tanks, Etc.

2000 cubic feet of air per minute from a 70 pound air-cooled, gasoline engine driven blower. . . Completely portable, entirely self-contained. . . Throttle controlled air volume, five hours' operation on one tank full of gasoline—quick starting, weather-proof, water-proof, dust-proof. . . Rain or shine, hot or cold, the Homelite Blower is ready when you want it, where you want it, and the way you want it. . . Sewer inspection departments and sewer cleaning and repairing crews need Homelite Blowers. . . Water departments and gas companies —electric and central steam companies—all have a corner in their maintenance trucks for Homelite Blowers.





HOMELITE PORTABLE PUMPS for Dewatering Ditches, Manholes, Excavations, Etc.

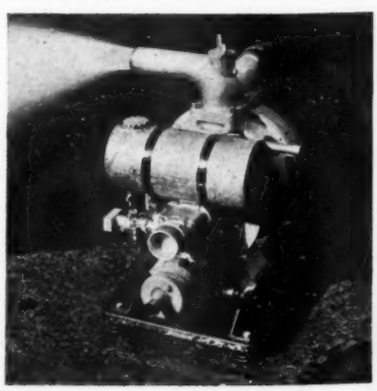
Homelite Portable Pumps with their self-contained Homelite gasoline engine can be installed anywhere on the job or where the emergency happens to land . . . 4000, 8000 or 15,000 gallons per hour from an easily carried self-contained unit or 35,000 gallons per hour from a two-wheel truck mounted unit. . . Mud, sand, solids up to 35%, are easily handled with the Homelite self-priming, non-clogging centrifugal pump with suction lift up to 28 feet and total heads up to 55 feet.

A. 1½", 4000 gal. per hour — 52 lbs. total weight including gasoline engine.

B. 2", 8000 gal. per hour — 79 lbs. total weight including gasoline engine.

C. 3", 15,000 gal. per hour — 91 lbs. total weight including gasoline engine.

D. 4", 35,000 gal. per hour — 800 lbs. complete with steel or pneumatic tired 2 wheel truck.



IMPROVING THE OPERATION OF A SMALL TREATMENT PLANT

Wherein Inexpensive Contrivances Have Played an Important Part

By C. G. WEBER
Superintendent
Sewage Treatment Works, Annapolis, Maryland

THE Sewage Treatment Works, of Annapolis, having a capacity of 3 M.G.D., was placed in operation on September 4, 1936. The treatment consists of coarse screening, pre-chlorination and primary sedimentation with separate sludge digestion in heated fixed cover digesters. The sludge is dewatered on vacuum filters.

The sewage flows by gravity to a pumping station where it receives pre-chlorination. It is then pumped through a force main to the treatment works about one mile from the pumping station.

The treatment works consists of two 150,000 gallon clarifiers, provided with sludge removal and grease skimming mechanisms; two 180,000 gallon fixed cover sludge digesters, provided with gas collection and heating coil systems; a vacuum sludge filtering system; and a fully equipped control laboratory.

Chlorination Improvements

Chlorine was originally applied to the raw sewage at a manhole on the interceptor 25 feet ahead of the pumping station and into two 10,000 gallon wet wells (Fig. 1). With this arrangement there was considerable loss of chlorine which was not absorbed by the sewage. Chlorine permeated the shredder room and other parts of the pumping station causing considerable damage to metal parts. Applications of chlorine at the rate of 20 p.p.m. seldom produced chlorine residuals in the clarifier effluents and residuals in the influent reaching the plant were not at all uniform. Furthermore, there was rapid accumulation of sewage solids in the center of each wet well which increased the chlorine demand as it accumulated. Several feet of solids would accumulate in two or three days.

To overcome these difficulties the chlorine solution was piped to the wet wells and applied behind a deflector placed in the wells as shown in Fig. 1. By thus changing the direction of flow of the sewage through the wells the solids were prevented from accumulating. Chlorine, applied as shown at the baffle, was thoroughly mixed with the sewage and uniform residuals appeared at the treatment plant, with chlorine dosages of 15 p.p.m. Whereas, formerly there was little or no correlation between chlorine applied and chlorine residuals, complete correlation now exists and chlorine gas is no longer noticeable in the pumping station.

There are two W & T vacuum type automatic chlorinators, the water supply for which is obtained from the Severn River. When the temperature of the water drops to 47° F. the formation of chlorine hydrate has created considerable operating difficulty.

A 1,000 watt heater placed inside the chlorinator was helpful but not entirely satisfactory and very expensive to operate.

A hot water coil installed in the recirculating line of our hot water boiler, worked perfectly. During the past winter water pumped from directly under the ice was used without any difficulty.

Improvised Grit Chamber

The sewage treatment plant is not provided with a grit chamber. As a result the digester and clarifier pipes became choked with grit, making it very difficult to withdraw a sludge from either unit. At one cleaning about 6 tons of grit was removed from the clarifiers. Grit also accumulated rapidly in the digester. The Annapolis system is one of those assumedly separate domestic systems.

At the influent of the plant there is a diversion chamber provided with a swing gate. Immediately in front of this gate I installed a steel dam, which made a very satisfactory grit trap (Fig. 2). The accumulated grit is removed daily, and for the past two years we have had no grit trouble.

Sludge Pumping

The withdrawal of raw sludge from the clarifiers was through two telescopic valves, into a sludge well. From the well the sludge was pumped to the digesters. Since the well was open to the air there were numerous complaints of odors therefrom during its use. Furthermore this method of removal required about six hours.

To eliminate these difficulties we removed the valves and piping and connected directly to the sludge pump suction lines, and we measure the pumpage in minutes. A gage, installed in the laboratory, indicates when the sludge is thick or too thin for further pumping.

Sludge Disposal

For disposal of the digested sludge the plant was equipped with a sludge storage tank 11′ 6″ long by 9′ 6″ wide and 10′ deep, inside dimensions. The available storage space was about 900 cubic feet. The sludge from this tank was pumped to a conditioning or ferric mixing tank, equipped with air diffusers for mixing the sludge with lime and ferric chloride. Lime was added from a lime feeder and ferric chloride was fed from an Omega Solution Feeder. The conditioned sludge then flowed to an Oliver Vacuum Filter having 65 sq. ft. filter area.

Chemical Requirements

For the first year of operations (1937), we used on a dry sludge solids basis 7.7% ferric chloride and 21% lime. As our anhydrous ferric chloride then cost $3.62 per hundred and lime cost 55 cents per hundred, our cost of chemicals per ton of sludge solids was $7.88.

We soon found that lime caused rapid cloth binding. After dewatering about 12 tons of dry sludge solids the filter cloth had

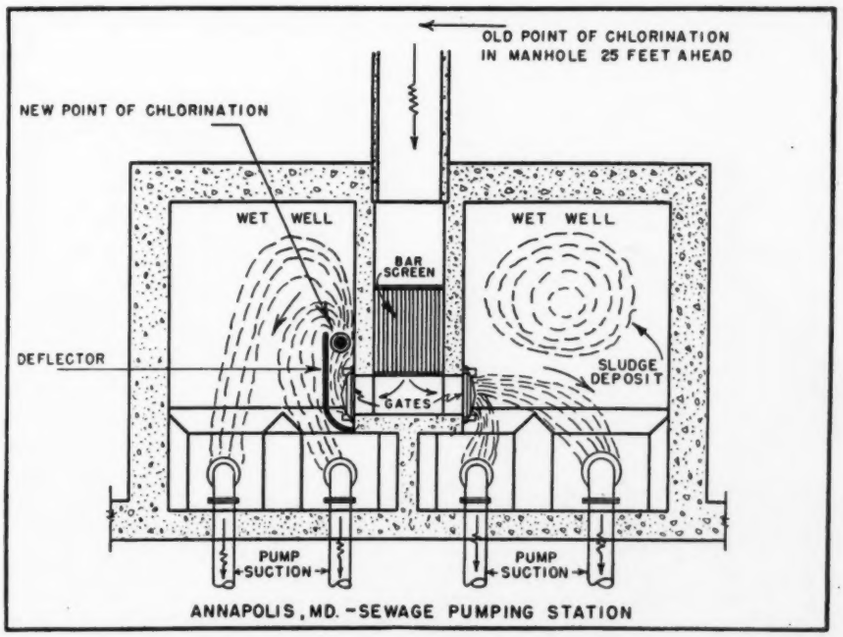


Fig. 1—Twin Pump Suction Wells
Before and After Installing Baffle, Which Prevents Sludge Accumulations and Chlorine Loss.

*A paper presented before the 15th Annual Meeting of the Maryland-Delaware Water and Sewage Works Association.

to be acid washed. This represented about 51 hours of actual filter service per cloth dressing.

In 1938 we substituted a mechanical stirrer in our conditioning tank in place of the air mixing method, and found that without any lime at all we could get good filtration when using 7.3% ferric chloride. This method increased our filter cloth life by 200%. That is we dewatered 36 tons of sludge solids, or got about 153 hours of actual service out of each filter dressing. This development reduced the cost of our chemicals per ton of digested solids to about $5.29 per ton of digested solids, a saving of $2.59 (33%). Added to this was the saving in filter cloth costs.

In 1939 we managed to get the ferric chloride consumption down to 4.6%. However, about half of the sludge filtered was partially elutriated, as, with permission of Mr. A. L. Genter of Baltimore (owner of elutriation patents), we started experimenting with sludge elutriation in our sludge storage tank during 1939.

Elutriation Experiences

Our first trials with partial elutriation showed such definite savings in chemicals, labor power and filter cloth that we arranged to change over to a better method of elutriating, and of dosing the elutriated sludge with coagulant; also a simpler and more direct method of feeding the dosed sludge to the Oliver Filter.

First of all this necessitated placing a sloping concrete bottom in the existing sludge storage tank for elutriation purposes. Without this bottom experiments had proved that we couldn't obtain at all times a sludge of uniform solid content from the flat bottomed tank for a complete filter run. I also found that the elutriated sludge coagulated so easily with ferric chloride or alum solutions that we could do away with the mechanical stirring.

Changing the bottom of the sludge storage tank and equipping it with a sludge and water mixing trough and swivel pipe for syphoning off the clear wash water or elutriate, after allowing the washed solids to settle out, reduced the available elutriation settling space to about 650 cubic feet. However, this did not handicap our operations, but greatly improved our economies.

Settled Sewage Proves Best

For the last six months I have been experimenting with elutriation and making various changes to get the best economies from this treatment with our very limited means. We tried elutriating with well water, brackish bay water and settled sewage from the Dorr Clarifier. The latter proved the most effective and least costly source of elutriate water for our sludge. The brackish bay water, nearest our plant, actually produced a wetter cake and required slightly more ferric chloride. This was somewhat contrary to expectations.

Arrangements

Our present set-up for elutriating and conditioning the digested sludge is shown in Fig. 2.

One of the telescopic sludge valves removed from the raw sludge well was placed in a 50 gallon steel drum on top of the sludge elutriation tank. When this valve is properly set by the hand-wheel there is just enough gravity head from the digestion tank to feed a steady stream of digested sludge into the drum. Settled sewage is pumped into the same drum, mixing with the digested sludge. The mixture then overflows a vertical pipe standing in the open drum and flows to the elutriation settling tank through a manhole on top of this tank. As the drawings show, the sludge and water are thoroughly mixed in a trough located in the top of the settling tank. The trough is equipped with baffles staggered at an angle. The mixture then flows into the tank, until it is practically full. After the solids have settled out, the clear supernatant is syphoned off by means of a 4-inch swivel overflow drain. This supernatant flows to the plant sump and is pumped back to the primary clarifier. The settled washed sludge is pumped to the conditioning tank, which will be described later.

In Fig. 3 is pictured the simple arrangement adopted for pumping elutriating water from the overflow trough of the primary Dorr clarifier through the window of the filter building to "washer tank" on top of the elutriation tank.

Results

At present we are dewatering elutriated sludge with about 1.7% ferric chloride and no lime. The price of ferric chloride has advanced from $3.62 per hundred in 1937 to $4.98 per hundred at present, or almost 38% increase. Despite this fact our present cost for ferric chloride per ton of sludge solids is but $1.69, which is $6.19 (78.5%) less per ton of sludge solids than in 1937 and $3.60 (68%) less per ton than in 1938.

To be entirely fair to our present elutriation results, if we were now paying the price of $3.62 per hundred for ferric chloride like in 1938, our present cost per ton of sludge solids

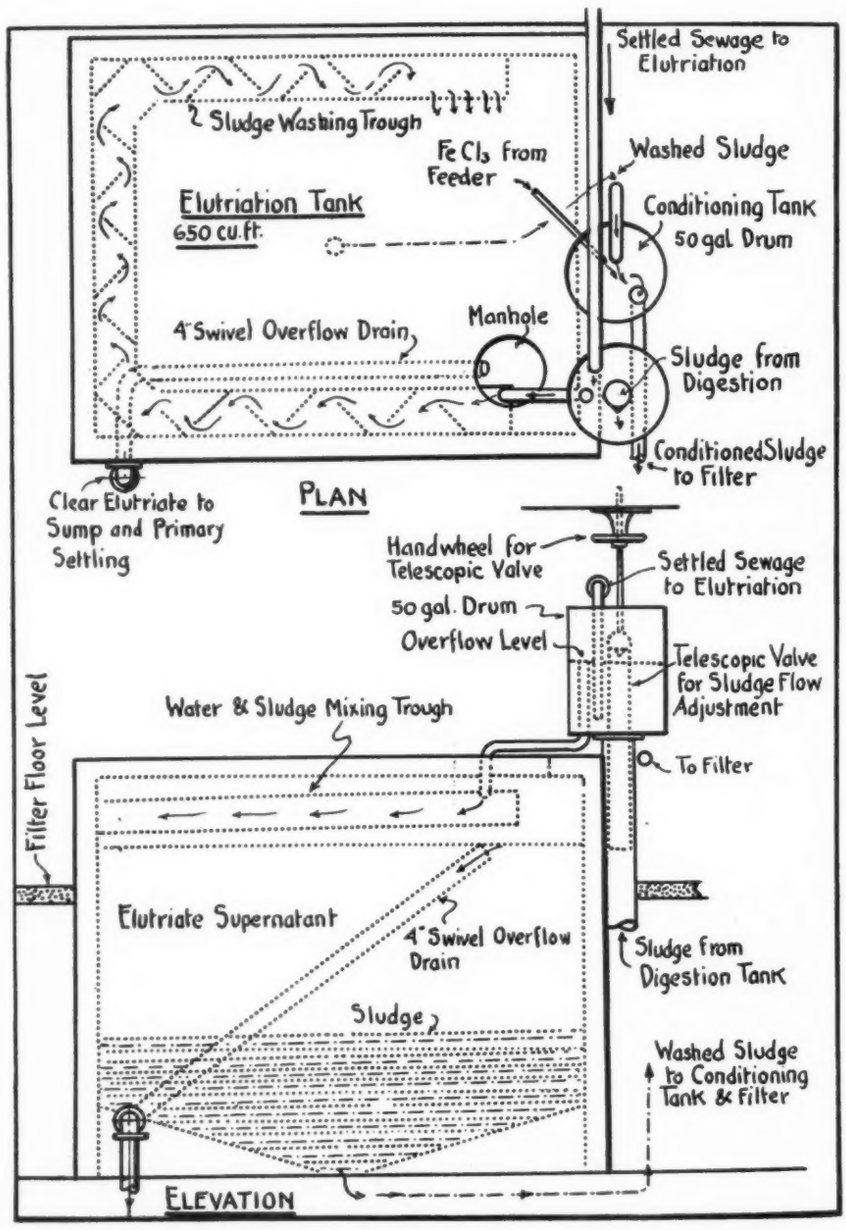


Fig. 2—Sludge Elutriation Arrangement
Sludge Storage Tank Converted Into Elutriator, Employing Settled Sewage as the Elutriating Water. Note Adjustable Mixing Tank at Top.

dewatered for ferric chloride would be $1.23 and the savings per ton of sludge solids dewatered would be $6.65, or 84.5% less than in 1937; and $4.06, or almost 77% less than in 1938.

However, with elutriated sludge at Annapolis there are other means of cutting chemical cost. We have made very successful filter runs on elutriated sludge when using commercial alum from our water treatment plant. Compared to anhydrous ferric-chloride, about three times as much commercial alum is required and the price of alum vs. ferric-chloride will determine the material to be used in the future. We tried alum on unelutriated sludge and found it unsatisfactory, as the conditioned sludge was difficult to filter and required much larger doses.

Other Savings

The savings in chemical costs are only a part of the story of elutriation economy. Our filter yields at this low chemical addition are from 8 to 10 pounds per square foot per hour and our filtering time, labor and electric current consumption has been cut in half. During 1939 when about half of our sludge was elutriated our filter blanket lasted for 123 tons of cake or over 520 hours of active service. We now hope to get 300 tons or about 1,200 hours of service out of a blanket costing about $27.

Sludge Mixing Arrangement

The details of our present sludge conditioning tank are shown in Fig. 4. This tank was made out of a 50-gallon oil drum and has no mechanical stirrer or air diffuser, so power for this purpose has been eliminated. By properly jetting the small stream of ferric chloride from the Omega Feeder into the inflowing stream of washed sludge, the sludge and ferric chloride or alum solution are thoroughly mixed. This is done by the agitation resulting from the inflowing sludge stream falling into the pool of sludge in the bottom of the small tank or drum. This pool is about seven inches deep and the inflowing stream displaces an equivalent amount out of the drum through a vertical pipe nipple overflow. This nipple can be lifted out of the drum at the end of filter runs so all of the conditioned sludge will be drained from the system to the filter.

With elutriated sludge this intimate flash mixing produces an excellent floc almost instantly. The conditioned sludge displaced from the drum flows downward through a feed pipe, through the end of the Oliver Filter tank to the center point without any delay. In other words the feed pipe is not the usual inverted syphon. We found that the inverted syphon was very unsatisfactory. Furthermore, feeding the sludge directly into one end of the filter resulted in good cake on half of the filter nearest the sludge inlet and poor cake on the other end of the drum. So we extended the pipe to the center.

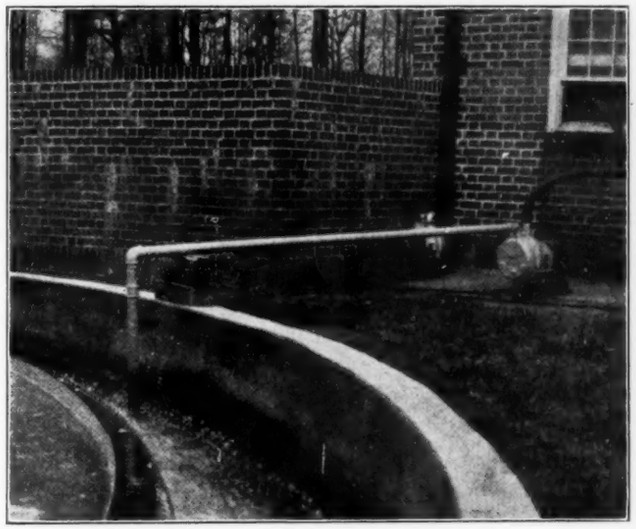


Fig. 3—Portable Homelite Pump
Delivers Settled Sewage to the Mixing "Washer Tank" (Fig. 3) at a Cost of 13c per Day.

In operating elutriation and filtration our set-up does not permit withdrawing clear elutriate while we are washing sludge because our settling tank is too small. However, as we filter sludge but two or three times every week, we draw the sludge from digester and wash it during the day preceding filtration. We then let the sludge settle over night, which produces a very clear elutriate and thick sludge. We syphon the elutriate off on the following morning and pump the settled washed sludge to

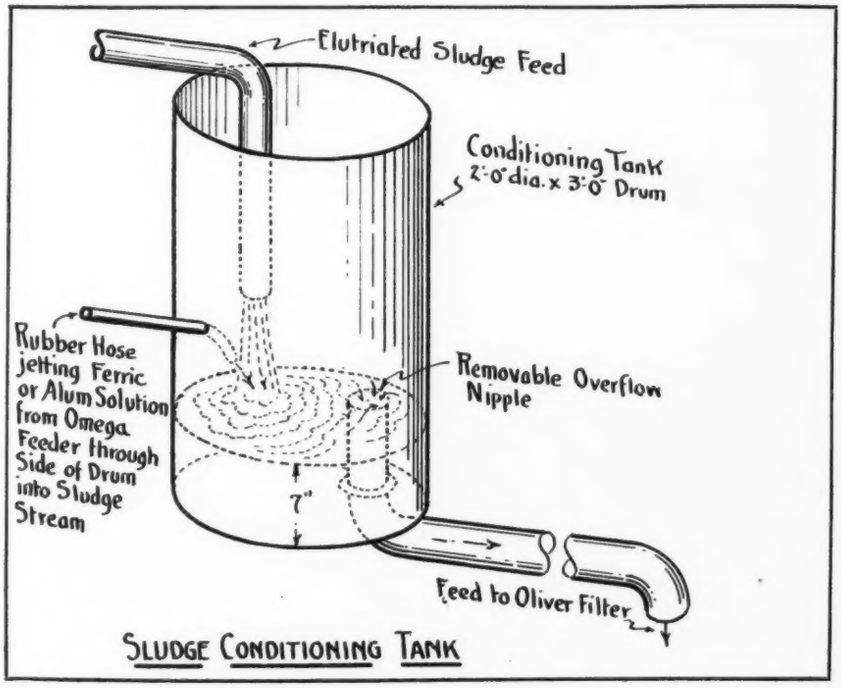

Elutriated Sludge Feed
Conditioning Tank
2'-0" dia. x 3'-0" Drum
Rubber Hose jetting Ferric or Alum Solution from Omega Feeder through Side of Drum into Sludge Stream
Removable Overflow Nipple
7"
Feed to Oliver Filter
SLUDGE CONDITIONING TANK

Fig. 4—Simple Sludge Conditioning Tank
From a 50-Gal. Oil Drum This Effective Mixing Unit Was Constructed. Seems to Be All That's Required for Elutriated Sludge.

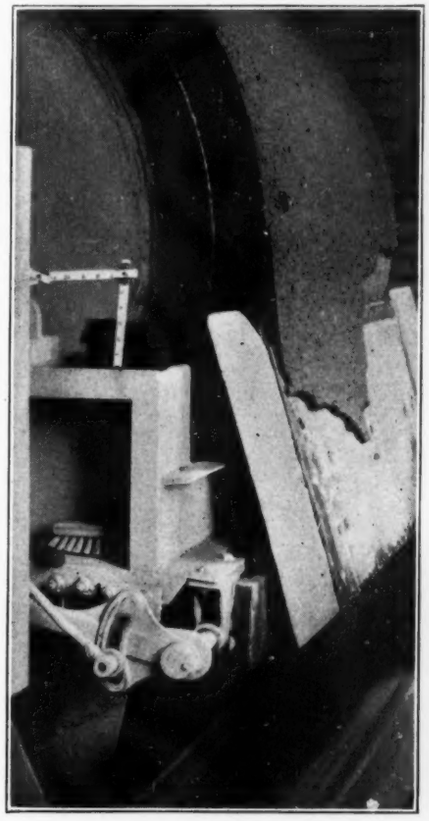


Fig. 5—Filter Cake
This ¾" Cake (8 to 10 lbs. dry solids/sq. ft./hr.) is Characteristic of Present Operations.

sludge conditioning and the filter. We generally use about four voulmes of elutriating water (settled sewage) to one volume of sludge. We filter about 2,200 pounds of sludge solids during one filter run and take about 3 hours to complete the run. Ordinarily we filter about 156 days every year, or three times a week.

Fig. 5 shows the filter cake now obtained from the elutriated sludge. Four cake thicknesses measure three inches, meaning the cake is about ¾" thick.

"Annapolis" Sludge Weigh-Recorder

Previous to the use of elutriation we had estimated the sludge solids dewatered by sampling the sludge collected in the storage tank and then measuring the cubic feet and pounds of sludge withdrawn from the tank by any filter run. When elutriation was adopted this method was not practical. I then devised an automatic self-dumping and recording sludge scale, shown in Figs. 6 and 7. The first is a sketch of this device. As can be seen this is controlled by adjustable weights, and the whole is attached to the supporting frame of the filter cake belt conveyor. At present this dumping scale is set, by the "adjusting weight" on the arm locking into the spring bolt, to release the hinged bottom door when exactly 33.3 pounds of sludge cake has accumulated in the scale box from the belt conveyor. The scale is frequently checked by diverting a dumped load to a pan on an ordinary beam scale. An ordinary revolution counter, fastened to the conveyor frame, is attached by a rod and spring to the weighted arm which closes the box bottom after each load is dumped into the truck below the box. The cake is sampled for moisture and solids determinations and by multiplying the number of cake dumps recorded on the counter by the weight of each dump and the percent solids present, the dry pounds of cake solids per run are easily obtained. The photograph (Fig. 7) shows this inexpensive and accurate device with the hinged door open above the plant truck.

Much for Little

All of the ideas, changes and labor relating to the foregoing changes in our treatment system were supplied by myself and others of the operating force. The cost of the materials and structural changes involved in elutriation, new sludge conditioning method and filter feeding and cake weighing amounted to less than fifty dollars.

The cost of pumping clarifier overflow (settled sewage), for elutriation with the little Homelite Portable Pump is very little, namely 13 cents per day of operation. This cost is more than offset by our saving in power for filtration.

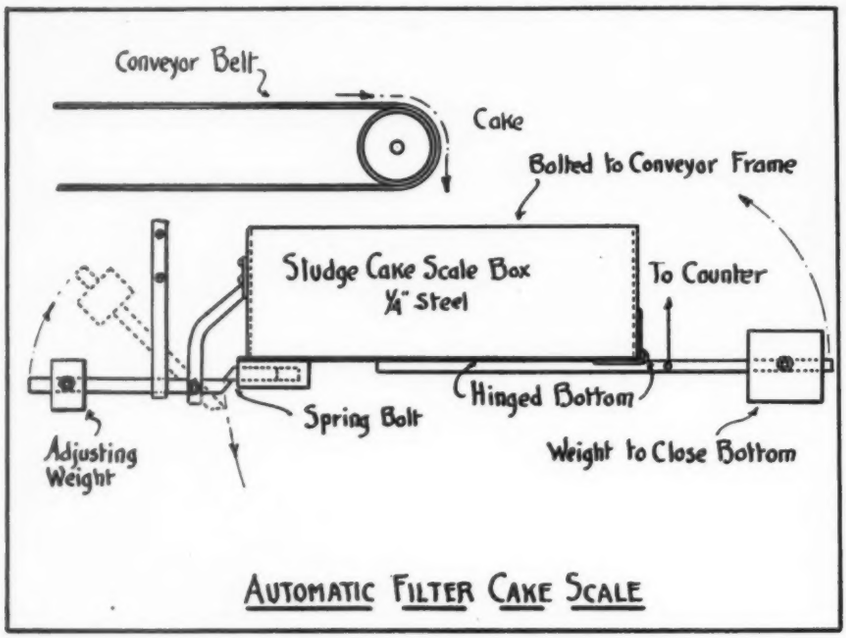


Fig. 6—"Annapolis" Automatic Sludge-Weigh-Recorder
Just a Home Made "Gadget," but It Does a Good Job of Giving Us a Record of Sludge Weight and Dumps Automatically—See Fig. 7.

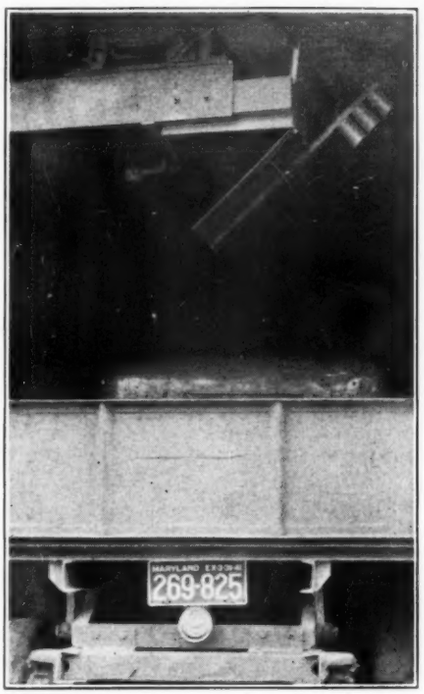


Fig. 7—The Self Dumping Weight-Recorder
Has Just Released Its Load of 33.3 lbs. of Filter Cake Into Truck—See Fig. 6.

HOURLY LOAD VARIATIONS IN RELATION TO SEWAGE TREATMENT PLANT OPERATION

By ELSON T. KILLAM

Consulting Engineer, New York City

The wide variations in the hourly load arriving at sewage treatment plants, due to the combined effect of variations in sewage strength and in rate of sewage flow, have previously been discussed by the writer.[1]

Data then available were confined to two plants, both located in Georgia. Investigations recently conducted on two systems in New Jersey involving widely different conditions than those of the two systems originally described, indicate surprisingly similar load variations.

Tests of 24-hour duration with frequent flow readings and separate analysis of hourly or two-hourly samples emphasize the following conditions in these four systems:

(1) A substantial portion of the total daily load arrives at the plant in a comparatively short operating period—see curves.

(2) The hourly variations and per cent of the total daily load arriving at the plant in any given period are not markedly different regardless of whether the load be expressed in terms of flow and B.O.D. content—or, expressed in terms of flow and suspended solids content.

(3) Load variations from hour to hour are surprisingly uniform regardless of the size of the system or other factors which might normally be expected to create widely different conditions.

(4) Hourly distribution of load and variations therein have important effects on plant efficiency and on operating procedure with many types of treatment plants, particularly chemical plants. These variables emphasize the desirability of providing for flexibility in design to allow variable operation.

[1] "Hourly Load variations as a Factor in Sewage Treatment Plant Operation"—WATER WORKS AND SEWERAGE; July, 1934; pp. 237-240.

Studying the Load Variations

A convenient method of summarizing sewage load variations is by means of cumulative load curves. To obtain data for such a curve, samples should be collected throughout a full 24-hour period, preferably at intervals of 15 minutes or ½ hour. These samples should be proportionate to the flow and each group of samples comprising a period of one or two hours' duration should be separately analyzed. It is also essential to take flow measurements at frequent and coincident intervals. In this way the total pounds of suspended solids or B.O.D. arriving at the plant during each hour of the day, may be ascertained. Cumulative load curves may then be constructed by selecting, first,

TABLE NO. 1—DATA RELATIVE TO CUMULATIVE LOAD CURVES

Curve Number	Location of System	Type of District Served	Average Flow—M.G.D.	Estimated Tributary Population	Date of Test Period	Distance from Sampling Point to Most Remote Point in System—Miles	Method Flow Measurements (*)	Data Relative to Samples
"A"	DECATUR, GA. (Shoal Creek Outlet Sewer)	Strictly Residential: Separate System	0.167	2,200	4 p. m., Sat., Oct. 28 to 4 p. m., Sun., Oct. 29 1933	2.5	90 deg. V Notch Weir	(a)
"B"	RAHWAY, N. J. (Rahway Valley Joint Trunk Sewer for 7 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	1.84	23,000	3 p. m., Mon., July 23 to 3 p. m., Tues., July 24 1934	7.8	90 deg. V Notch Weir	(a)
"C"	ELIZABETH, N. J. (Elizabeth Valley Joint Trunk Sewer for 12 Municipalities)	Separate System: Residential, with some Industries and some Business Districts	14.19	228,000	2 p. m., Thur., Aug. 2 to 2 p. m., Fri., Aug. 3, 1934	18.0	Venturi Meter	(b)
"D"	ATLANTA, GA. (Main Sewer Entering Peachtree Creek Plant)	Combined System; Residential, with some Industries and some Business Districts	15.22	110,000	8 a. m., Fri., May 3 to 8 a. m., Sat., May 4, 1933	8.0	Recording Gage at Station Rated by Current Meter	(a)

* All Flow Readings at half-hour intervals.
(a) Samples collected at half-hour intervals—each group of four composited and analyzed.
(b) Samples collected at half-hour intervals—each group of two composited and analyzed.

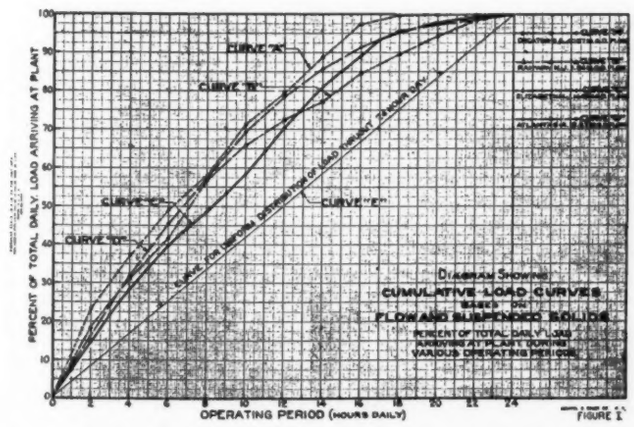


Fig. 1—Cumulative Loads, Based on Floc and Suspended Solids

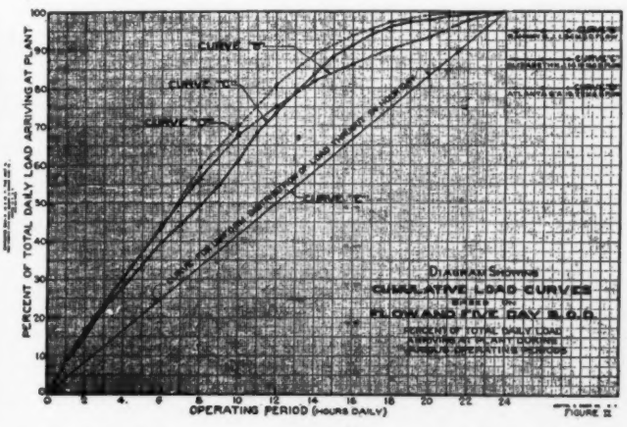


Fig. 2—Cumulative Loads Based on Flow and 5-Day Oxygen Demand

the hour at maximum load, and subsequently taking each consecutive hourly load in order of descending magnitude, and plotting of 24-hour curve. Loads expressed in terms of flow and suspended solids content, or flow and B.O.D. content, or both, may be used for the study.

Typical examples of such curves, showing data for the four system investigated, are shown in Figures 1 and 2, the former being based on load determined by suspended solids content and flow, and the later upon B.O.D. and flow.

Statistics, showing the type of system, average daily flow, tributary population, and other information, for the four systems investigated, are shown on Table 1.

Similarity in Load Variations

In view of substantial differences in type and size of the four systems referred to in Table 1, the relatively small difference in the load developed in any given number of hours in each of the systems, is of especial interest.

The Decatur (Ga.) system, for instance, involved a sewage flow of only 0.16 m.g.d. with a population of only 2,200 people in a strictly residential area, and with the most remote point in the area served only 2½ miles from the point of sampling on the trunk sewer.

On the other hand, the Elizabeth Valley System involved a total flow of 14.19 m.g.d. from a tributary system comprising several hundred miles of sewers serving 228,000 people. Remote portions of the system are at least 18 miles distant from the point at which flow measurement and samples were taken.

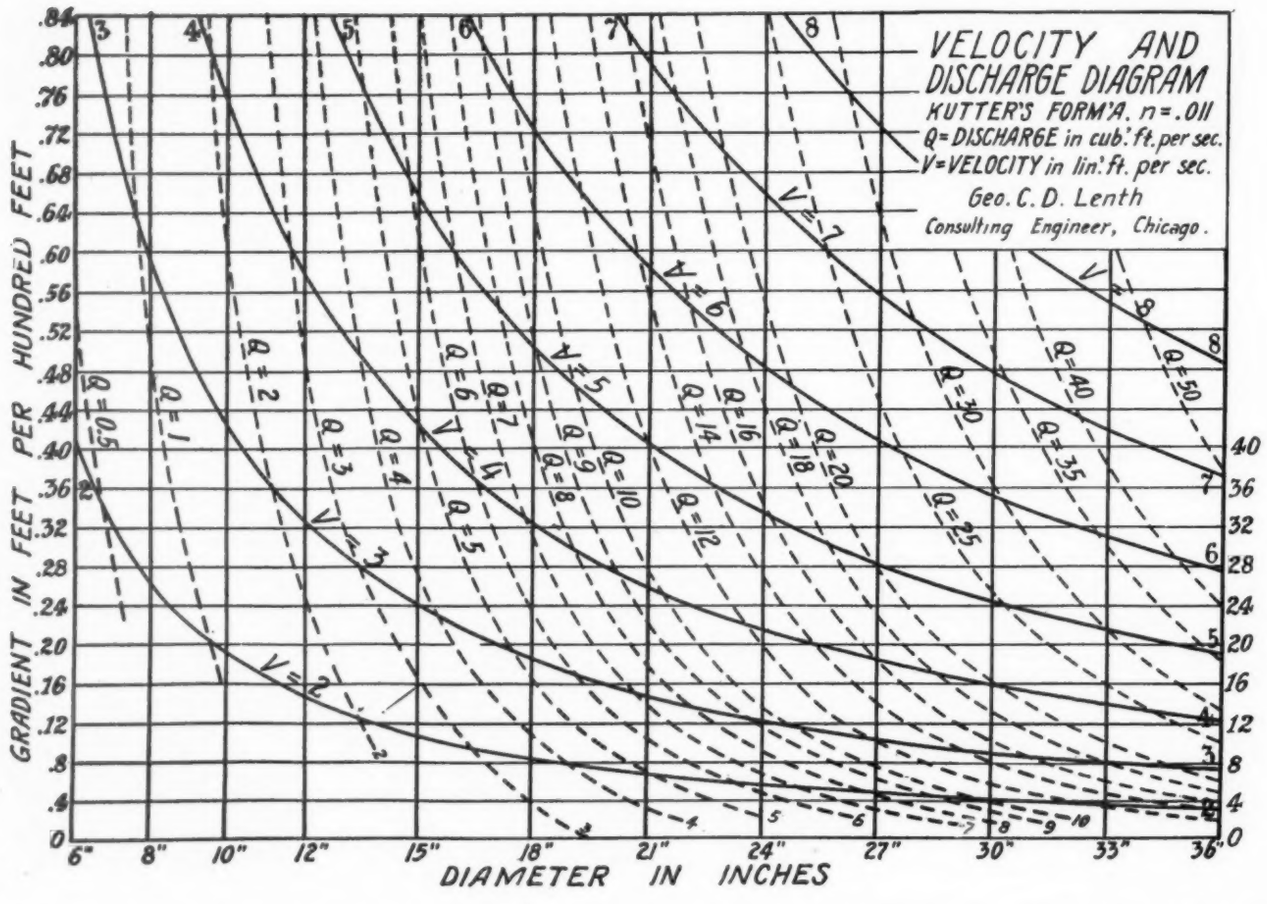
It might well have been expected that in such an extensive system as the latter, the variations would be smoothed out and greatly reduced in magnitude before the sampling point was reached by the passing flow. Comparison of all four curves, however, indicates that in no instance, within a fixed number of hours of operation, does the total cumulative load arriving at the plant vary by more than 13 per cent. Examination of the curves also discloses that the distribution of the load, based on suspended solids, agrees very closely with the load based on 5-day B.O.D.

What It Means

The similarity of these curves indicates that load variations in substantial proportions may be expected on every sewerage system. These variations and their effects are accordingly important in the design and operation of sewage treatment plants. in the measurement and evaluation of treatment plant efficiency; and, in the collection of river samples below sewer outlets during investigations of the pollution of receiving streams.

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub.' ft. per sec.
V=VELOCITY in lin.' ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)

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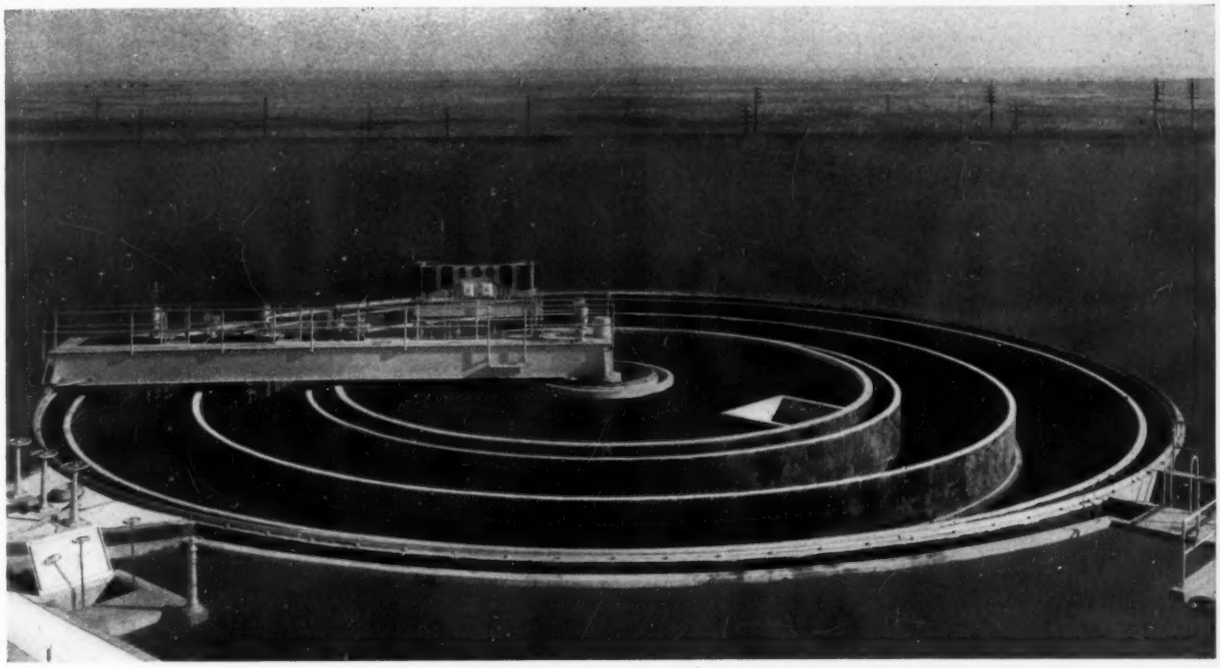

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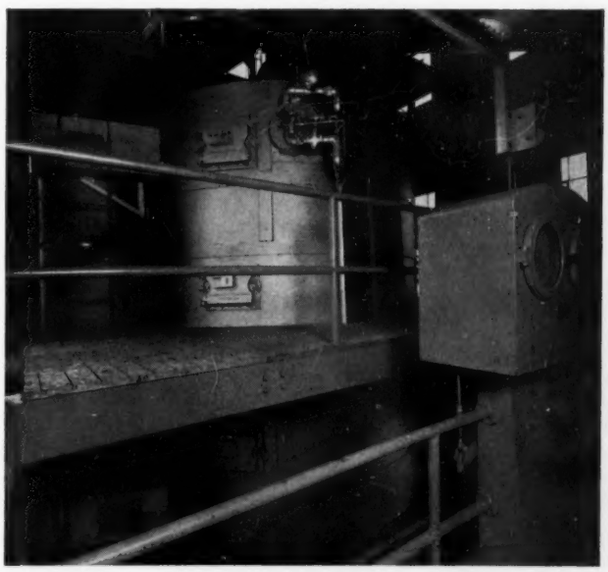

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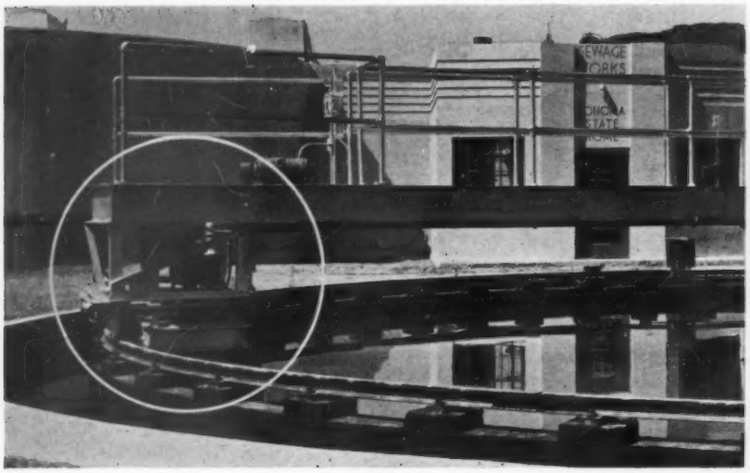

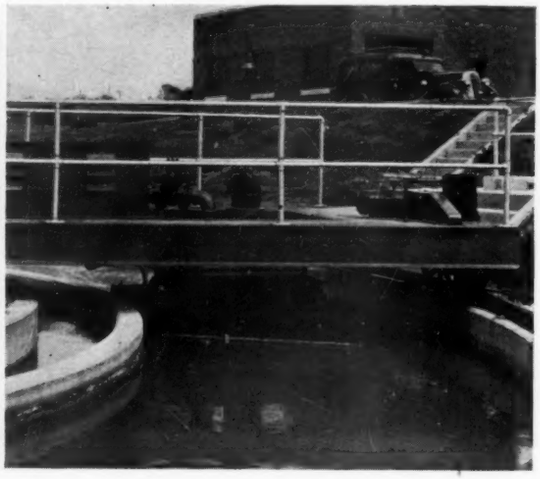

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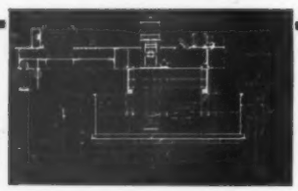

Above: Section across filter bed.

Above left: An Automatic Magnetite Filter installed integral with a Dorr Clarifier. Cleaner element in circle.

Above right: Magnetite Filter installed in an annular ring separate structure.

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THE BIOFILTRATION SYSTEM

By ANTHONY J. FISCHER, Ph.D.
The Dorr Company, Inc., New York, N. Y.

UP TO about five years ago the activated sludge process was increasing in favor over trickling filter treatment, even for small plants. This trend developed in the face of the generally recognized fact that the activated sludge process does not readily withstand sudden shock loads such as from creamery, laundry and other wastes that are in a large measure responsible for poor performance and sludge bulking in the average small plant.

A number of reasons contributed this general trend, not the least of which was the greater potential flexibility obtainable in activated sludge plants where it proved possible to vary the volume and distribution of air and regulate sludge return in accordance with the load requirements.

With the realization that the average small activated sludge plant could not take varying loadings with any degree of success, usually requiring frequent use of the plant by-pass, came the intensive study of methods of more adequate control of the trickling filter and its operation. An outcome of this work was the development of the so-called "high-rate" filter (more properly defined as the "high-load" filter) one form of which is used in the Biofiltration System.

The Biofiltration System

In the Biofiltration System there are two important considerations—one involving the minimum dose applied to the filter, the other involving the recirculation of filter discharge material back to a settling or detention tank preceding the filter.

Characteristic, but not all necessarily essential, elements of the process involve:

(1) Presedimentation of the sewage before it is applied to the filter;
(2) The use of dosing rates on the filter *in excess of* 800 gallons per cu. yd. of filter medium;
(3) Clarification of the filter effluent in either the detention tank preceding the filter or in a separate clarifier;
(4) Recirculation of filter effluent, final clarifier effluent, or final clarifier sludge, back to the new incoming feed;
(5) The use of filter beds having stone depths *as low as* three feet;
(6) The use of two-stage treatment where very strong sewages are encountered, or where a high degree of treatment is desired.
(7) Average daily filter loadings based on raw sewage *as high as* 5.0 pounds of B.O.D. per cu. yd. of filter medium;
(8) Substantially continuous filter dosing.

Action of Process

The continuous passage of the sewage and recirculated effluent through the system at a relatively high rate causes a uniform action to take place through the entire filter bed depth. Also, the surface of the filter is kept wet at all times, while the detention period in the settling or detention tank never becomes excessively long. This results in a uniform action throughout the filter bed depth, continuous filter bed unloading, prevention of surface ponding and filter fly breeding, and the prevention of septic action in the settling tank at times of low flow.

Because of the relatively short detention or contact period in the filter, complete stabilization is not secured in the filter alone. This unit rather acts as a "colloider" and serves to coagulate material and agglomerate the very fine particles in the sewage in much the same way as is accomplished in chemical precipitation processes and to a considerable degree in the first stages of the activated sludge process. At the same time, however, there is an appreciable reduction in B.O.D. and a build-up of dissolved oxygen which is utilized to complete the stabilization in the detention tank. In this way the Biofiltration Process may be considered as the full equivalent of the activated sludge process, the filter being the source of oxygen and micro-organisms, and the clarifier or detention tank serving as the aeration tank as well as the settling unit.

Typical Flowsheets

Typical Biofiltration Process flowsheets involve the use of either single-stage or two-stage treatment as follows:

1. *Single-Stage (Intermediate) Treatment.*

With this flowsheet (shown in Figure 1) an effluent having a quality between that of a primary treatment and a standard trickling filter may be obtained. With normal strength sewage (200-250 p.p.m. B.O.D.), a reduction of about 50% to 60% may be expected where the volume of recirculated flow is equal to at least twice the volume of the new feed to the system. Whether the final effluent should be taken off at the clarifier or the filter depends on the strength of the raw sewage and the recirculation ratio employed. With weak sewage and/or with high recirculation ratios, a better grade effluent may be obtained from the clari-

The Two Stage Biofilter Plant of Covina, California.

The Secondary Effluent Is Chemically Flocculated and Clarified in a Clariflocculator. The Final Effluent Passes Through Sand Filters.

The Single Stage Biofilter Plant of Sonoma, California.
The Secondary Effluent Is Rendered More Attractive by Passage Through a Magnetic Filter.

fier. With strong sewage and/or low recirculation ratios, the filter effluent should be better. This is illustrated by the plant operating results given in Table 1 for a strong and a medium sewage. It is observed that in the case of the first the clarifier effects no improvement, but rather the reverse.

2. *Single-Stage Complete Treatment.*

This flowsheet (shown in Figure 2) differs from that of Figure 1 in that the filter effluent is settled in a separate secondary clarifier before being discharged from the system. This flowsheet should produce results on a par with standard trickling filters. It should be noted that this flowsheet involves the return of filter discharge and/or secondary clarifier material. The secondary clarifier material may be effluent, sludge or any combination of the tank contents.

A popular modification of this flowsheet (see Figure 3) involves the recycling of part of the secondary clarifier to the filter while part of the filter effluent and all of the secondary sludge is recycled to the primary clarifier. With this arrangement both clarifiers may be of the same size and have the same detention and overflow rate.

With this flowsheet, overall B.O.D. reductions of 75 to 85% may be expected when a normal sewage is being treated and a recirculation ratio of about 2 is maintained. Typical results obtained from large-scale plant operation are shown in Table 2.

3. *Two-Stage Complete Treatment.*

Figure 4 shows three modifications of a two-stage complete treatment plant. These vary as to the point of take-off from the primary system and point of delivery to the secondary system. Flowsheet (a) is a preferred form from the standpoint of avoiding short-circuiting of primary settled sewage directly to the secondary filter. Actual operating results, however, indicate that regardless of this short-circuiting around the primary filter in flowsheets (b) and (c) a final effluent low in B.O.D. may be obtained. Flowsheet (b) has certain advantages in arrangement of the plant structures with minimum interconnecting piping. This piping may be readily arranged to provide a maximum of plant flexibility at little additional cost. One such arrangement is shown in Figure 5-a where gravity flow cannot be obtained through the entire plant. Another, as shown in Figure 5-b, is suitable where sufficient head is available to carry the flow through all the plant structures without auxiliary pumping other than for recirculation. A plant of the latter type is now under construction at Liberty, N. Y. (This plant has since the writing of this article been placed in operation.—Ed.) Here the total head available from the primary clarifier inlet to the final clarifier overflow weir was only about 6 feet.

Many modifications of this two-stage treatment flowsheet are possible. For example, a separate clarifier may be used for primary settling, final effluent may be recirculated to the raw sewage, etc.

With a normal strength sewage and a recirculation ratio of 1 to 1 in each stage, this two-stage system should effect an overall reduction in B.O.D. of 90-95%, with the production of a well nitrified effluent, high in dissolved oxygen and low in suspended solid. In this respect this flowsheet may be regarded as producing results the full equivalent of the activated sludge process. Typical plant results are given in Table 3.

Factors Influencing Design and Operation

A study of these and experimental plant results indicate that the following are the most important factors that influence the design and operation of Biofiltration Systems:

(1) B.O.D. loading on the filter (expressed as lbs. B.O.D./cu. yr. of filter medi/day);

(2) Recirculation ratio (ratio of recirculated to new incoming flow);

(3) Clarifier detention and overflow rate.

Of secondary importance are dosing rates on the filter, method and continuity of application of the sewage to the filter, and design of the filter bed as to selection of filter media and provision for adequate ventilation. Within limits, the depth of the filter bed apparently has little effect, 6 to 8 foot beds giving little improvements over shallow beds 3 to 4 feet in depth.

B.O.D. Loadings

The capacity of a filter for removing B.O.D. is not yet fully understood. Results obtained to date (shown in Figure 6) indicate that the strength and character of the raw sewage is a determining factor. These average curves show that with increasing sewage strength a greater amount of B.O.D. may be removed per unit of volume of filter medium. They also show that with a given strength of sewage the overall removals increase up to a certain point, after which there is no further reduction regardless of the increase in loading. A very interesting feature is, however, that the capacity for B.O.D. removal does not fall off as the result of the super-loadings.

Where much stronger sewage or trade wastes are treated, such as creamery, cannery, beet sugar, distillery waste, etc., much higher B.O.D. removals may be obtained. For example, B.O.D. removals as high as 5.23 lbs./cu. yd./day were obtained when treating beet sugar waste having a raw B.O.D. of 1,650 p.p.m. Also in the case of a distillery waste having a B.O.D. of 20,000 p.p.m., such phenomenal removals as 15.4 lbs./cu. yd./day were obtained.

The data of Figure 6 are based on 24-hour samples composited according to flow. Tests on catch samples collected at times of peak sewage flow (and/or strength) showed that peak B.O.D. loadings of about three to four times the daily average may be successfully handled.

Recirculation

That recirculation is of distinctive advantage is shown by the data given in Table 4, where Biofilter single-stage complete and intermediate operation are compared to standard trickling filter results, where the B.O.D. loadings were essentially the same.

Normally a plant design should allow for *minimum* recirculation ratios given in Table 5. For stronger sewages, proportion-

ately higher ratios should be used. With all types of plants, *the higher the recirculation ratio, the better the overall results obtained.*

Clarifier Design

That the clarifier following a filter becomes increasingly more important as the dosing rate on the filter is increased has been shown by Levine. Using a 6-ft. deep filter, he found the results given in Table 6. In these tests the material (milk waste) was passed through the filter only once. A similar trend is followed, however, when recirculation is employed.

As in the case of the activated sludge process, clarifiers in Biofilter plants should be rated on overflow rates as well as on detention period. The former is by far the most important factor. Table 7 shows the preferred basis of design for the various types of plants. Both overflow rates and detentions should be based on the total flow to the clarifiers, including the recirculated flow. In general, within limits the greater the recirculation ratio the higher are the overflow rates and the lower are the detention periods that may be used without adversely affecting results.

Dosing Rates

Provided the dosing rate on the filter does not fall below about 4 to 8 m.g.a.d. and does not exceed about 100 to 125 m.g.a.d., this factor appears to have very little effect on Biofilter operation. The purpose of maintaining more than the lower rate is to aid in preventing the accumulation of solids in the filter bed. Another object is to keep the surface wetted more or less continuously, and so prevent the propagation of filter flies. The maximum rate must not be exceeded; otherwise the filter bed will be flooded.

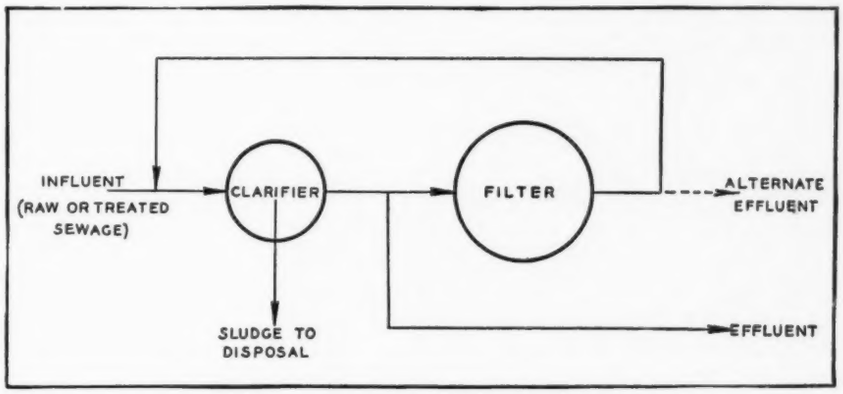


Fig. 1— Single Stage Intermediate Treatment.

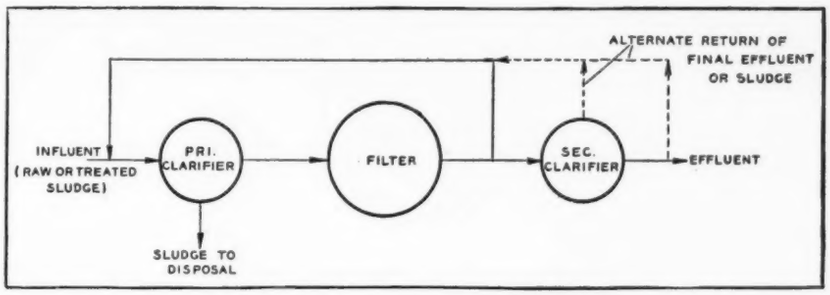


Fig. 2—Single Stage Complete Treatment.

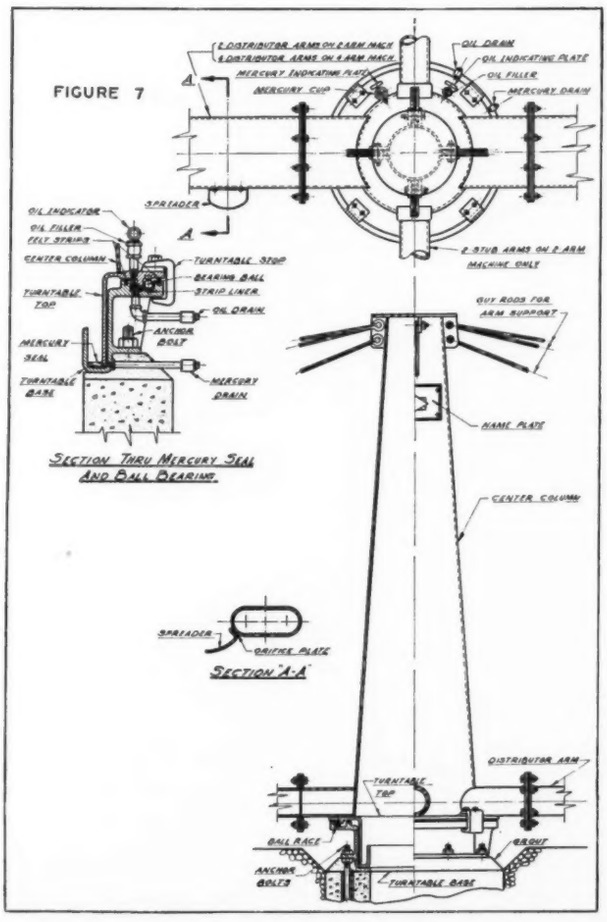


Fig. 7—Construction Details of Distributor Mechanism.

TABLE 1

Relative Quality of Primary Filter and Detention Tank Effluent with Weak and Strong Sewage—Single-Stage Intermediate Treatment.

	Petaluma, Calif.	*Healdsburg, Calif.*
Suspended Solids—ppm		
Raw Sewage	394	200
Clarifier Effl.	126	69
Filter Effl.	132	120
B. O. D.—ppm		
Raw Sewage	636	304
Clarifier Effl.	257	87
Filter Effl.	216	125
Per cent Removal		
Sus. Solids—Clarifier	68.0	65.5
—Filter	66.5	40.0
B. O. D.—Clarifier	59.6	71.4
—Filter	66.0	58.9
Dosing Rate—M.G.A.D.—Raw	5.0	8.0
Dosing Rate—M.A.G.D.—Total	19.5	49.0
Recirculation Ratio	2.9	5.1
Aver. Raw B.Q.D. Loading—#BOD/c.y./day	5.38	3.99
Clarifier O'flow Rate—Gals./sq. ft./24 hrs.	1170	1120

TABLE 2

Single-Stage Complete Treatment—Plant Results.

	Petaluma, California	*Camarillo,* California*	*San Mateo, California*	
Suspended Solids—p.p.m.				
Raw Sewage	437	223	201	233
Primary Clar. Effluent	167	78	157	80
Final Clar. Effluent	48	22	60	33
Primary Removal—Per cent	61.8	65.0	21.8	65.7
Total Removal—Per cent	89.0	90.0	70.1	85.8
B.O.D.—p.p.m.				
Raw Sewage	644	285	231	238
Primary Clar. Effluent	419	127	131	143
Final Clar. Effluent	53	26	45	16
Primary Removal—Per cent	35.0	55.4	43.3	40.0
Total Removal—Per cent	91.8	91.0	80.5	93.3
Dosing Rate—MGAD—Raw	4.90	5.33	19.0	10.2
Dosing Rate—MGAD—Total	17.2	27.8	69.5	38.4
Recirculation Ratio	2.50	4.2	2.65	2.76
Aver. Raw Loading—#BOD/cy/day	5.35	2.60	7.57	4.17
Aver. Settled Loading—#BOD/cy/day	3.48	1.16	4.30	2.50

*State Hospital Plant.

Filter Bed Design

Most Biofilter plants now in operation or under construction use filter beds having a 3-ft. depth of filter medium. As in the case of conventional low rate filters, tests have shown that an increase in filter depth improves the B.O.D. reduction but slightly. This is shown by the experimental data given in Table 8.

Crushed stone 1½" to 2½" in size has been used in primary filter beds, while ¾" to 1" stone has been found satisfactory for secondary beds in warm climates. For average conditions, however, it is felt that 2" to 3½" and 1½" to 2½" stone would be better in the primary and secondary units respectively.

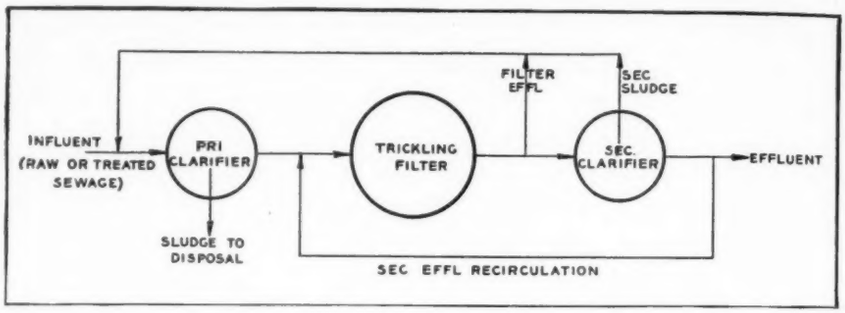


Fig. 3—Single Stage Complete Treatment Modified Flowsheet.

TABLE 3

Two-Stage Complete Treatment—Plant Results.

	Petaluma, Calif.		*San Mateo, Calif.*		*Healdsburg, Calif.*
Suspended Solids—p.p.m.					
Raw Sewage	394	462	233	201	249
Primary Effluent	126	150	33	60	64
Final Effluent	38	43	30	17	29
Primary Removal—Per cent	68.0	67.5	85.8	70.2	74.3
Total Removal—Per cent	90.3	90.7	87.1	91.5	88.2
B.O.D.—p.p.m.					
Raw Sewage—p.p.m.	636	521	238	231	395
Primary Effluent	257	333	16	45	84
Final Effluent	33	28	13	13	27
Primary Removal—Per cent	59.6	36.0	93.2	80.5	78.7
Total Removal—Per cent	94.8	94.6	94.6	94.3	93.2
Dosing Rate—MGAD—Raw	5.0	10.6	10.2	19.0	7.90
Dosing Rate—MGAD—Total	19.5	37.1	38.4	69.4	49.0
Recirculation Ratio	2.90	2.50	2.76	2.65	5.19
Aver. Raw Loading—#BOD/cy/day	2.69	4.78	2.08	3.78	2.53

TABLE 4

Results of Biofiltration vs. Standard Trickling Filter Treatment.

	Petaluma, Calif. Single-Stage Complete Treatment		*Healdsburg, Calif. Single-Stage Intermediate Treatment*	
	(Biofilter)	(Std. Filter)	(Biofilter)	(Std. Filter)
Suspended Solids—p.p.m.				
Raw Sewage	437	410	269	244
Primary Effluent	167	170	64	102
Final Effluent	48	85	..	49
Primary Removal—Per cent	61.8	58.6	76.1	58.2
Total Removal—Per cent	89.0	79.3	76.1	79.8
B.O.D—p.p.m.				
Raw Sewage	644	640	395	390
Primary Effluent	419	455	84	285
Final Effluent	53	166	..	115
Primary Removal—Per cent	35.0	29.0	78.7	26.9
Total Removal—Per cent	91.8	74.1	78.7	70.5
Dosing Rate—MGAD—Raw	4.90	4.83	7.9	8.2
Dosing Rate—MGAD—Total	17.15	4.83	49.0	8.2
Recirculation Ratio	2.5	0	5.2	0
Aver. Raw Loading—#BOD/cy/day	5.35	5.25	5.27	5.40
Aver. Settled Loading—#BOD/cy/day	3.48	3.73	1.12	3.94
Clarifier Overflow Rate Gals./sq. ft /24 hrs	1095	252	1120	187

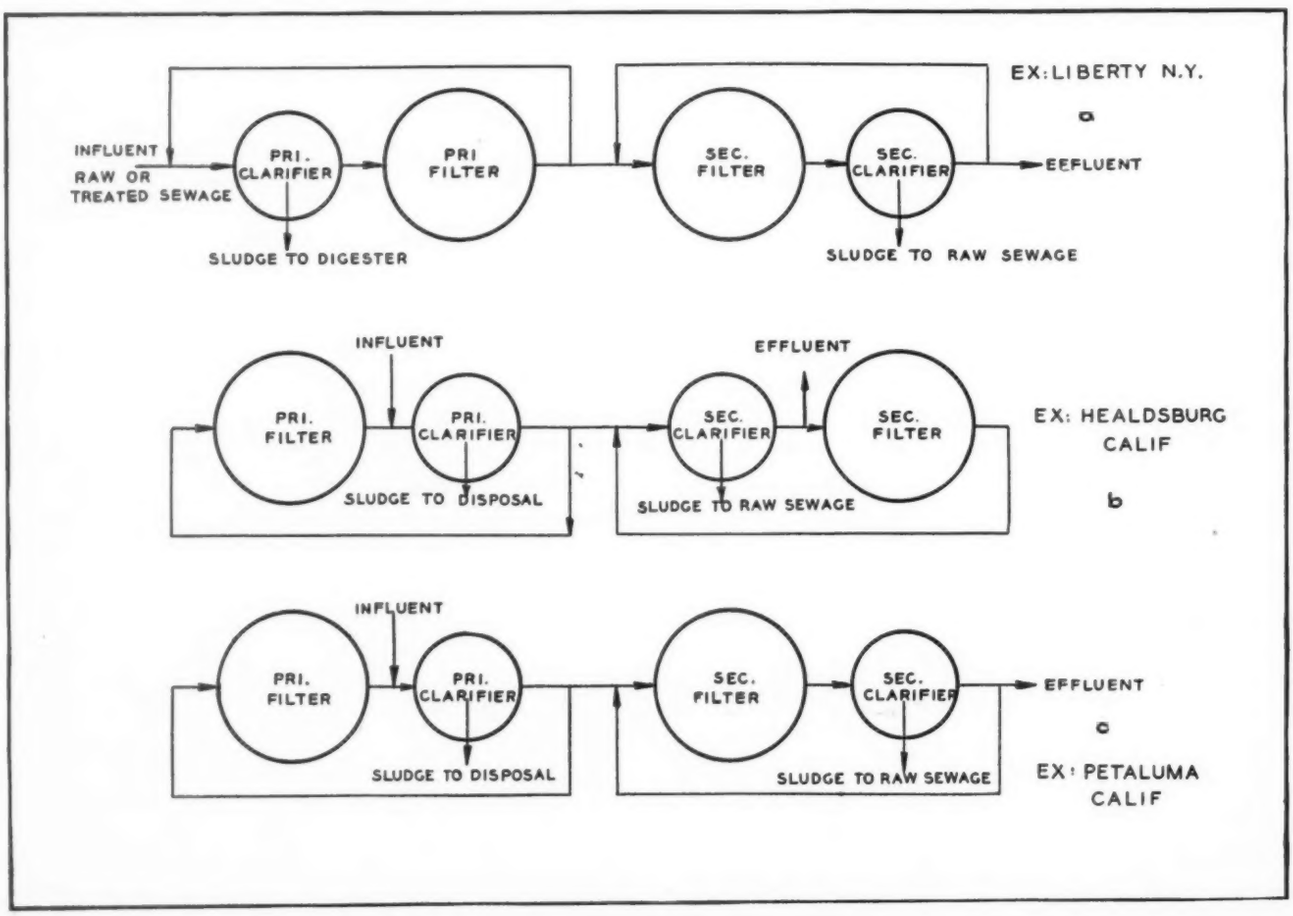


Fig. 4—Two-Stage Complete Treatment.

The filter media should be supported on a grid or underdrain system that will allow a free get-away or filter effluent so that good natural ventilation is obtained. It is questionable whether artificial ventilation would ever be required, especially where shallow beds are used.

Distributor

To take care of the high rates of application used in connection with the Biofiltration Process, special types of distributors have been developed to operate at heads as low as 18" to 24" above the stone surface. Where the flow fluctuation is considerable (over 3:1), the arms have two compartments, one above the other. The bottom compartments are designed to handle any desired proportion of the maximum design flow, quantities in excess of this being taken by the top compartments. Details of the mechaism construction are shown in Fig. 7.

Field of Application

Considering the flexibility in design and operation as shown by the foregoing data, the Biofiltration System may be applied to the treatment of sewage and trade waste ranging from weak domestic sewage to strong industrial wastes, with the reduction in B.O.D. normally ranging from 50% to 95%. It is particularly adapt-

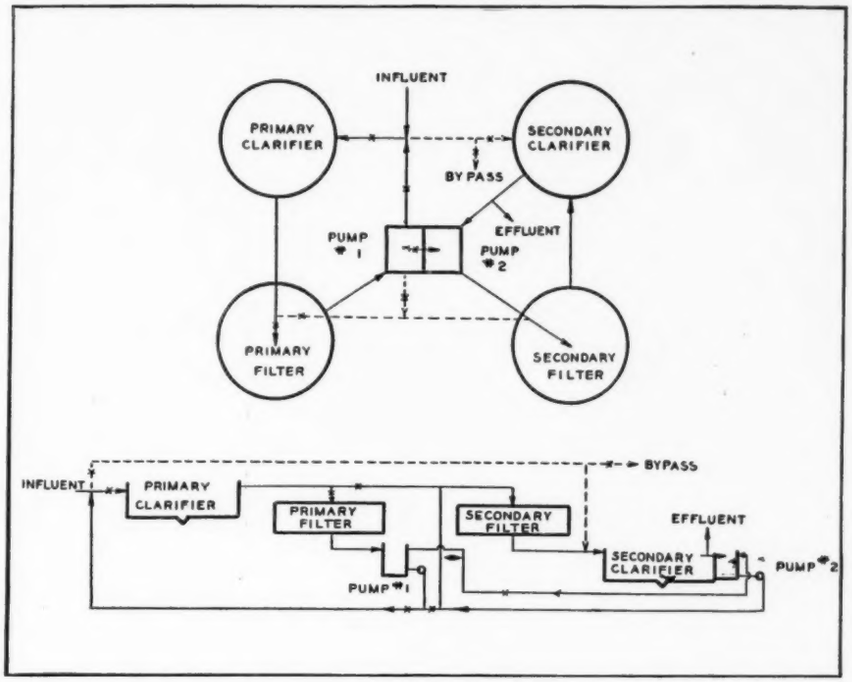


Fig. 5[b]—Two-Stage Flowsheet Gravity Flow Thru Plant.

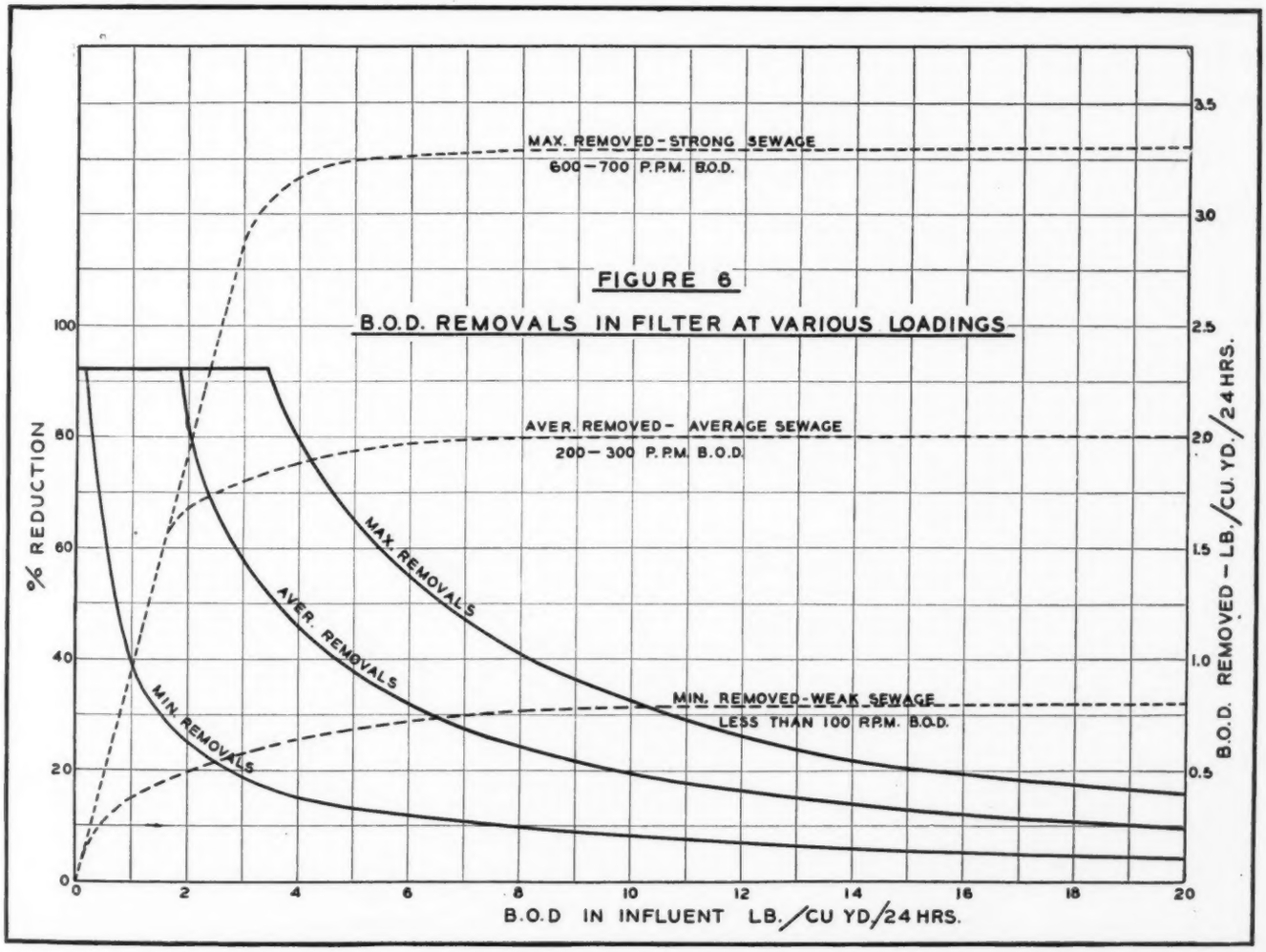


Fig. 6—B.O.D. Removals Observed at Various Loadings.
(Illustrating the upper capacity but the remarkable stamina of the high-rate biofilter under severe loadings.)

able to such cases where a municipal sewage treatment plant receives occasional or seasonal loads of industrial wastes such as from packing houses, dairies, textile mills, canneries, etc. Another application is for partial pre-treatment of industrial wastes before they are discharged to the city sewers. In this connection some test data on distillery waste treatment as shown in Table 9 are of interest. In Test 1 the standard two-stage Biofiltration was used, while in Test 2 the filter effluents were recycled back to the filters rather than to the detention tanks. In Test 3, the primary filter effluent was applied directly to the secondary filter instead of back to the primary detention unit. The effect of this was to give a single-stage filter 6 ft. deep. In Test 4 no recirculation was used, but each filter effluent was settled. It will be noted that these results confirm those obtained on weaker sewage in that recirculation is shown to be of decided advantage, better results being obtained when the filter effluent is recycled back to the detention tank. The results also show that a 3-ft. depth of filter medium accomplishes almost the same reduction in B.O.D. as does a 6-ft. depth. It was found in these tests that although the pH values of the feed were very low, it was not necessary to add any neutralizing agents provided the B.O.D. loading capacity of the filters was not exceeded. This filter loading capacity varied, depending on the flowsheet employed. In the regular Biofilter flowsheet the primary filter was capable of handling a raw B.O.D. load of 18 to 20 lbs./cu. yd./day. This phenomenally high loading has hitherto never been obtainable in trickling filter operation. It indicates that with adequate control facilities and with a rational basis of design, trickling filters as applied in the Biofiltration System are capable of satisfactorily treating sewage or trade wastes under an extremely wide variety of conditions.

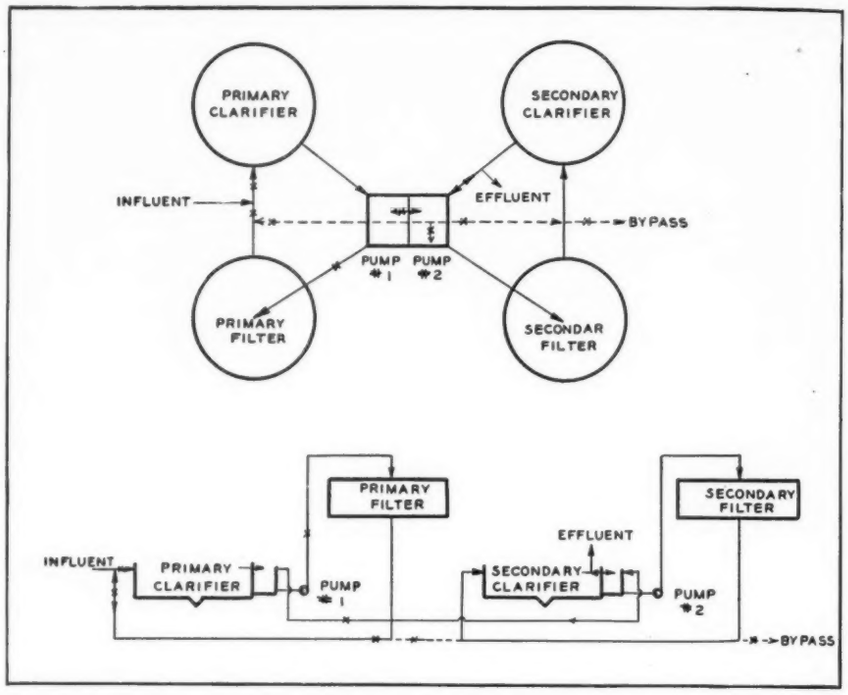


Fig. 5—Two-Stage Flowsheet Clarifier Effluents Pumped to Filters.*

Conclusions

1. The degree of treatment of sewage may be varied over a wide range by the use of the Biofiltration System.
2. The single-stage process in which one filter and one clarifier is used, will effect B.O.D. reductions of 50-60%.
3. The single-stage complete system, using one filter and two clarifiers, will give B.O.D. reduction of 75-80%.
4. In the two-stage system where two filters and two clarifiers are used, B.O.D. reductions of 90-95% may be effected.
5. The chief factors that influence the design and operation of all types Biofilter plants are B.O.D. loading on the filter, the

TABLE 5

Minimum Recirculation Ratios for Various Strengths of Sewage.

B.O.D.—Raw Sewage	*Recirculation Ratio (Recirculated Flow) Raw Sewage Flow* Single-Stage Intermediate Treatment	Single-Stage Complete Treatment	Two-Stage Treatment (Each Stage)
Up to 150 p.p.m.	1.0	0.75	0.5
150-300 p.p.m	2.0	1.5	1.0
300-450 p.p.m.	3.0	2.25	1.5
450-600 p.p.m.	4.0	3.0	2.0
600-750 p.p.m.	5.0	3.75	2.5
750-900 p.p.m.	6.0	4.5	3.0

TABLE 6

Relative B.O.D. Removals by Filter and Post-Settling at Various Filter Dosing Rates (Levine).

Dosing Rate M.G.A.D.	*Lbs. B.O.D. Removed Per Cu. Yd. of Filter Medium* Filter Only		Post-Settling		Total	*Per cent Removed by** Filter	Post-Settling
2.0	0.235	+	0.049	=	0.284	83.0	17.0
4.0	0.344	+	0.145	=	0.489	70.4	29.6
8.0	0.572	+	0.457	=	1.029	55.2	44.8
16.0	1.53	+	1.25	=	2.78	55.1	44.9

*Figures represent per cent of total B.O.D. removed for which each unit was responsible.

TABLE 7

Biofiltration System—Clarifier Design.

	Single-Stage Treatment Intermediate	Complete	*Two-Stage Treatment*
Primary Clarifier			
O'flow rate—gals./sq. ft./24 hrs....	800-1000	1200-1500	1200-1500
Detention—Hrs.	2.0	1.5	1.5
Secondary Clarifier			
O'flow rate—gals./sq. ft./24 hrs....	.....	800-1000	1200-1500
Detention—Hrs.	.....	1.5	1.5

TABLE 8

Test Results on Single-Stage Biofilter System, Evperimental Unit.

	Test 1	*Test 2*	*Test 3*
Filter Depth	6 ft.	4 ft.	2 ft.
Raw Dosing Rate—M.G.A.D.	12.0	12.0	12.0
Total Dosing Rate—M.G.A.D.	60.0	60.0	60.0
Recirculation Ratio	4.0	4.0	4.0
Suspended Solids—P.P.M.			
Raw Sewage	315	293	288
Primary Clar. Effluent	160	133	147
Final Clar. Effluent	46	58	57
Primary Removal—Per Cent	49.3	54.6	49.0
Total Removal—Per cent	85.4	80.2	80.2
R.O.D.'s—P.P.M.			
Raw Sewage	233	268	273
Primary Clar. Effluent	165	205	179
Final Clar. Effluent	63	52	67
Primary Removal—Per cent	29.2	23.5	34.5
Total Removal—Per cent	83.0	80.6	75.5
Raw Loading No. B.O.D./c.y./day	2.40	4.15	8.45
Dissolved Oxygen—Final Eff	4.5	4.0	2.9

TABLE 9

Biofilter Test Results—Distillery Waste

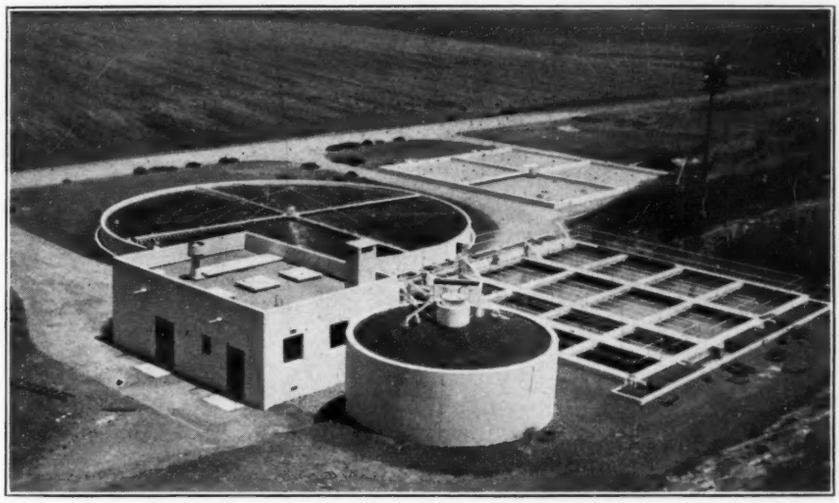
Test No.	I	II	III	IV
Raw Dosing Rate—M.G.A.D.	0.784	0.784	0.653	0.784
Total Dosing Rate—M.G.A.D.	26.1	26.1	32.7	0.784
Recirculation Ratio	32	32	49	0
B.O.D.—5-day				
Raw	18,700	19,500	18,500	15,800
Primary Filter Effluent	1,610	8,710	2,630	21,500
Secondary Filter Effluent	1,100	5,900	1,900	5,000
Primary Removal—Per cent	91.4	55.3	85.8	....
Total Removal—Per cent	93.2	69.8	89.7	68.4
pH Value				
Raw	3.2	2.5	2.4	2.8
Primary Filter Effluent	7.3	5.2	7.5	3.9
Secondary Filter Effluent	7.3	6.8	7.5	6.0
Per cent Total Solids				
Raw	1.80	1.80	2.10	1.64
Primary Filter Effluent	0.26	0.28	0.22	1.24
Secondary Filter Effluent	0.24	0.20	0.24	0.28
No./c.y./day	8.79	9.16	7.07	7.43
Aver. Raw B.O.D. Loading—				

volume of recirculated flow, and the clarifier overflow rate and detention.

6. The capacity of a filter for removing B.O.D. apparently varies with the strength and characteristics of the applied sewage. With normal strength domestic sewage, 2.0 lbs. of B.O.D. per cu. yd. of filter medium per day appears to be the maximum that can be removed.

7. Recirculation of filter effluent back to the detention tank is of material aid in controlling the degree of purification obtained. In general the recirculation ratio should be increased in proportion to the increase in strength of the raw sewage. In the case of normal strength sewage this ratio should be about 2.0 for single-stage intermediate treatment, 1.5 for single-stage complete treatment and 1.0 for two-stage treatment.

8. The detention tank design becomes increasingly more important as the B.O.D. load on the filters is increased. The average clarifier overflow rate should not exceed 800-1000 gals./sq. ft./24 hrs. in the case of single-stage plants, and 1200-1500 gals./sq. ft./24 hrs. in the case of two-stage plants. Average clarifier detentions should not be less than 1.5-2.0 hours.



Single Stage Complete Treatment Biofilter Plant—Camarillo State Hospital, California.

9. Within a range of about 8.0 to 100 m.g.a.d., dosing rates apparently do not affect the action in the filter bed as long as the limiting B.O.D. load is not exceeded.

10. Increasing the filter bed depth beyond 3 ft. gives only a slight improvement in results and, therefore, is not warranted.

11. The Biofilter System may be applied for the pre-treatment of very strong industrial wastes. In the case of distillery wastes having a B.O.D. of about 20,000 p.p.m., over 90% reduction in B.O.D. may be effected in a single-stage 3-ft. depth filter.

12. In the treatment of strong wastes such as distillery waste, very high B.O.D. loadings may be applied to the filters without seriously affecting their capacity for B.O.D. reduction. In the case of distillery waste, B.O.D. loadings of 18-20 lbs./cu. yd. were applied. The removals were 15-18 lbs./cu. yd./day.

CONCERNING REMOVAL OF GREASE FROM SEWAGE

By FRANK L. FLOOD

Metcalf & Eddy, Engrs., Boston, Mass.

The paper by Gorden J. Wiest on "Degreasing Sewage," appearing in the December, 1938, issue of Water Works and Sewerage,† is a noteworthy contribution toward solving sewage problems. It supplies us with a plant scale demonstration of the value of chlorine in conjunction with aeration in the removal of grease from sewage. At Lancaster, Pa., the value of the process is largely in the improvement apparently effected in the operation of the subsequent activated sludge process. However, the aero-chlorination process may also assume considerable importance in conjunction with skimming-sedimentation tanks in primary treatment of sewage prior to discharge into diluting waters where it is desirable to reduce the offensive condition ordinarily produced by grease balls and sleek.

In studying the analytical results, the writer was somewhat surprised by the relatively low quantity of skimmings removed even with aero-chlorination as compared with quantities removed at several plants where no provision is made for aeration or chlorination. The first thought was that the percentage of increase in quantity of grease removed as scum was the important factor to consider. A further study of the figures presented by Mr. Wiest indicated that the outstanding effect of the aero-chlorination process was not in the quantitative increase in grease removed as scum but in the increase in the removal of grease by sedimentation, as shown by the analysis of the sewage and effluent. To illustrate, the writer has computed the grease removal on the pounds per million gallon basis for the test periods given in Table III of Mr. Wiest's paper.

The striking figures to compare in this table are that whereas the weight of grease in the scum was increased by aero-chlorination from 0.2 to 1.9 lb. per m.g. dry basis, the apparent quantity of grease removed based on analyses of the sewage and effluents increased from 67 lb. per m.g. without aero-chlorination to 141 lb. per m.g. with aero-chlorination. The increase in removal based on weight of skimmings, amounting to 1.7 lb. per m.g. is insignificant compared with the apparent increase in removal of 74 lb. per m.g. indicated by the analyses to have gone down with the solids removed by the primary settling units.

Duration of test, 1938	Feb. 15-21	Mar. 4-9	Mar. 16-21
Air used, cu. ft. per gal.	0	0.14	0.14
Chlorine used, p.p.m.	0	0	2
Wet grease removed, lb. per m.g.	1.6	3.0	12.5
Grease removed in scum dry basis, lb. per m.g.*	0.2	0.5	1.9
Grease in raw sewage, p.p.m.	21	26	21
Grease in effluent, p.p.m.	13	13	4
Apparent removal of grease, p.p.m.	8	13	17
Grease in raw sewage, lb. per m.g.	175	216	175
Grease in effluent, lb. per m.g.	108	108	34
Apparent removal of grease, lb. per m.g.	67	108	141
Percent reduction of grease	38	50	80

rise to many notions and ideas regarding best methods.

†*Reprinted on pages 197-202 following.*

LAKESIDE ENGINEERING CORPORATION

222 W. ADAMS STREET CHICAGO, ILLINOIS

AERO-FILTERS FOR THE HALVORSON-SMITH PROCESS OF SEWERAGE PURIFICATION

Theory and Advantages

The Aero-Filter is a device designed to distribute sewage on the filter bed in an even, continuous and rainlike manner. Both the rotary and the disc types developed by the Lakeside Engineering Corporation are based upon the fundamental principle that best filtration is obtained when the filter bed is evenly and entirely covered by a continuous 24 hour rain of sewage, thus using *all* the bed *all* the time. The application of this theory by the Aero-Filter results in:

1. Excellent momentary distribution eliminating recirculation for dilution purposes.

2. Reduction in raw sewage B.O.D. ranging from 84% to 94% with single stage operation and from 88% to 99% with single stage operation followed by filtration or with two stage operation.

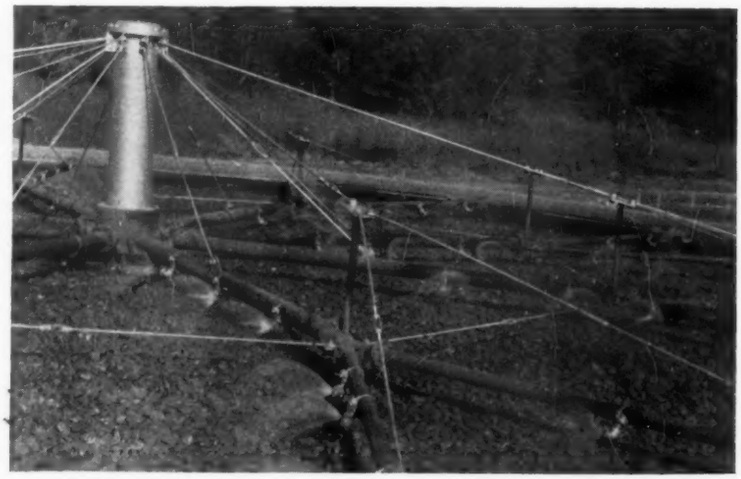
3. Low first cost since the Aero-Filter requires only from 1/7 to 1/8 the size of a standard filter of equal capacity.

4. Lowest known operating costs.

5. Minimum troubles from odors, freezing, ponding and filter flies.

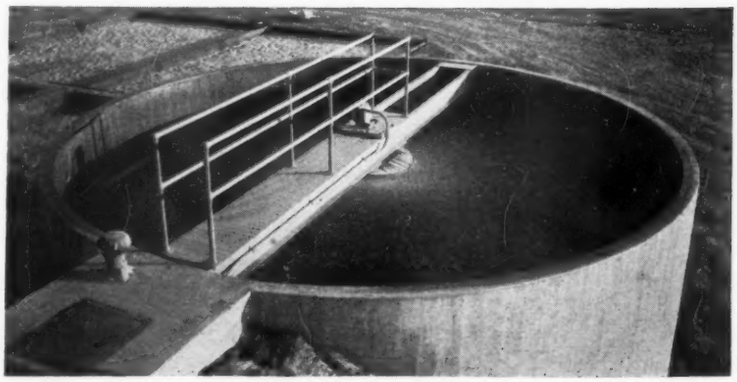
Rotary Type — 31 to 84′ Dia. Filter

The principle of the multiple arm rotary distributor is well indicated in the illustration at the right. The number of arms, branches and nozzles is varied to fit the needs of the special problem. Further regulation is obtained by adjustment of the nozzles which can be made to discharge directly downward upon the filter, directly upward or in any intermediate position. The angle of discharge can also be changed to any point of the compass, and the orifice nozzles are easily interchangeable in the field. A Lakeside engineer will be present when these units are placed in operation, to pan-test the filter bed and make the proper distribution adjustments.



Disc Type — 8 to 34′ Dia. Filter

The motor-driven disc distributors range in size from 12″ to 34″ in diameter and are designed to operate at from 260 to 360 r.p.m., the speed for any given size of filter being constant. The discs are divided into three equal segments each segment being equipped with vanes for dividing the flow of sewage and shunting it uniformly over the filter bed.



Advantages:

1. The disc distributor will not clog and there are no nozzles to clean;

2. Satisfactory operation under widely varying rates of flow;

3. No mercury seals or packing glands to require attention;

4. Fool-proof construction, distribution is fixed by disc design and cannot be changed by the operator.

Send for bulletin 108 for a complete working description of the Aero-Filter as used in the Halvorson-Smith Process.

DEGREASING SEWAGE

Experiences With the Aero-Chlorination Method

By GORDON J. WIEST

Chemist Sewage Treatment Works, Lancaster, Pa.

The separation of grease and oils from raw sewage is recognized as important to most sewage works operators, because the presence of these buoyancy producing materials in sewage lowers primary sedimentation efficiencies. Furthermore, they apparently interfere with efficient aeration and final clarification in the activated sludge process.

The method for degreasing sewage has been to aerate the sewage, utilizing air diffusion, for a short period as it flows through a channel or tank ahead of sedimentation tanks. This method has been practiced in a number of activated sludge type plants. The theory is that a violent diffusion of air bubbles sweeps the particles of grease and oils to the surface where coalescence and floatation results. The removal of the grease follows the pre-aeration and is effected by tank skimming by hand or with the aid of mechanical devices.

History

H. A. Faber, of the Chlorine Institute, in 1937 reported an improvement of this method of grease separation as a result of an experimental study conducted under his direction on a full plant scale at the Woonsocket, R. I., Sewage Treatment Works. Faber's method* was to admit gaseous chlorine into the air line serving the grease separation tank. This method of employing chlorinated air for grease separation has now come to be known as degreasing by "Aero-Chlorination." Faber reported an average chlorine dosage of 1.5 p.p.m. (based on sewage flows), with an average detention period of six minutes, increased the grease removal from 189% to 442% as compared to the use of aeration alone and employing the same quantity of air and contact period. The percentage increase in grease removal was based on pounds of wet grease (scum) removed per million gallons of sewage treated. Keefer and Cromwell, at Baltimore, Maryland, conducted similar experiments on a semi-plant scale at the Back River Sewage Treatment Works which results* confirmed Faber's findings at Woonsocket.

Lancaster Conditions

An investigation of the grease and oils present in the sewage at the South Plant in Lancaster, Pennsylvania, led me to believe that our difficulties could be minimized by attempting a method to increase the efficiency of our grease separation facilities. A laboratory investigation showed that grease and oils were present in the raw sewage delivered to the South Plant in rather variable and also comparatively high quantities. This laboratory investigation included a study of the grease content of the activated ("return") sludge. The "return sludge" at the South Plant averaged 21.63% (dry basis) grease, while the "return sludge" at the North Plant averaged but 5.0% grease. Briefly, Lancaster, Pennsylvania, has two sewage treatment plants—both being conventional activated sludge type design with separate sludge digestion. The North Plant was placed in operation in December, 1934, and has produced a high quality effluent with a minimum of difficulties. The South Plant, placed in operation in May, 1935, has since that time continuously offered a variety of problems which interfere with good operation.

The Lancaster Plants were designed for pre-aeration ahead of the primary sedimentation tanks. Screenings and grit are removed ahead of the pre-aeration channels. The pre-aeration channels are 6.5 feet in depth with diffuser plates on the bottom of the channels. The air delivered to these channels is measured and recorded in the Main Building. The grease removal after pre-aeration is effected by means of mechanical skimmers which carry the grease across the surface of the primary sedimentation tanks to the effluent end, where cross-skimmers remove the grease to collection pits. The grease is removed from the collection pits to the digestion tanks as required. The operation of the skimmers is not continuous; they are placed in operation for an average of five non-consecutive hours daily. The average detention period in the primary sedimentation tanks is 1.75 hours.

A Form of Aero-Chlorination Tried

The use of a form of Aero-Chlorination with hopes of improving grease separation was started at the South Plant under plant scale conditions in August, 1937. Chlorine in a gaseous form could not be injected into the air line serving the pre-aeration channels. So, a W. & T. vacuum type solution feed chlorinator was set up to feed chlorine in solution directly to the raw sewage just ahead of air diffusion. The chlorine solution feed line was anchored in front of a baffle submerged directly ahead of the sewage delivery line. This insured thorough mixing. The dosing of the chlorine (as at Woonsocket and Baltimore[1-2]) has been calculated on the basis of raw sewage flow, for ease in interpretation and weighing of data—including costs of the procedure.

Point of Chlorine Application
(Pre-aeration channel, with chlorinator house on left. Note the violent aeration at this point, for rapid and most effective distribution of small dosages of chlorine.)

A number of preliminary tests were made alternating aeration alone with Aero-Chlorination—as we shall designate the procedure, even though not strictly Aero-Chlorination. Comparisons were made from the appearance of the grease collecting on the surface of the primary sedimentation tanks. Aero-Chlorination invariably produced more grease on the primary tanks than aeration alone. Variable dosages of chlorine were applied to the sewage mixed with air and it was found that chlorine was lost when applied in excess of 3.0 p.p.m. (This gives some indication of how closely the air blowing followed the chlorine application.) An average of only 2.0 p.p.m. has been applied throughout the experimental measurements, to avoid possible loss of chlorine, and also because preliminary results indicated that a dosage of 2.0 p.p.m. was effective for the treatment desired.

Analytical Procedure

The performance of Aero-Chlorination, under plant scale conditions, was measured during defined experimental periods by determining the grease content of the raw sewage ahead of pre-aeration and of the effluent from the primary sedimentation tanks. The percentage grease removal was computed from the analytical

results. The grease content of the raw sludge was also determined and the total grease removed computed. The method for the grease determinations followed Standard Methods of Water & Sewage Analysis (A.P.H.A.). The grease extractions were made, using petroleum ether throughout the experimental measurements reported. The grease was removed from the collection pits daily during experimental measurements and the weight was recorded after draining for not less than one hour. The weight of the grease was reported on a wet basis as pounds of wet grease removed per million gallons of sewage treated. The performance of Aero-Chlorination was compared with aeration alone, then without aeration or chlorination, and then chlorination alone. The grease content of the activated ("return") sludge was reported from time to time, since it is felt that the grease content of the "return sludge" may determine the efficiency of the activated sludge during aeration of the sewage sludge mixtures.

Results

Aero-Clorination Alone

Experimental measurements were made from August 14th to 24th, 1937, using Aero-Chlorination. The chlorine dosage was 2.0 p.p.m. The experimental measurements continued from August 26th to 31st, 1937, using aeration alone. The results are shown in Table I. On the basis of the weighed pounds of wet grease removed per million gallons of sewage treated, Aero-Chlorination increased the grease removal 308% (see table) over the treatment using aeration alone. Laboratory analytical results showed a grease removal of 76%, using Aero-Chlorination and a grease removal of 53%, using aeration alone.

These experimental measurements were repeated from September 5th to 15th, using Aero-Chlorination and comparative tests were made September 20th to 30th, using aeration alone. The chlorine dosage was 2.0 p.p.m. The results appear in Table II. On the basis of pounds of wet grease removed per million gallons of sewage treated, Aero-Chlorination increased the grease removal 373% over the treatment using aeration alone. Laboratory analytical results showed a grease removal of 78%, using Aero-Chlorination, and a grease removal of 63%, using aeration alone.

TABLE I
AERO-CHLORINATION VS. AERATION ALONE

Date (1937) August	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
14	3.6	0.12	2.0	11.3
15	5.8	0.18	2.0	7.4
16	3.6	0.12	2.0	17.4
17	3.5	0.11	2.0	16.2
18	3.2	0.11	2.0	10.9
19	2.9	0.10	2.0	11.2
20	2.9	0.10	2.0	12.5
21	2.9	0.09	2.0	10.6
22	2.3	0.08	2.0	5.6
23	2.6	0.08	2.0	18.3
24	4.0	0.13	2.0	14.1
Average	3.4	0.11	2.0	12.3

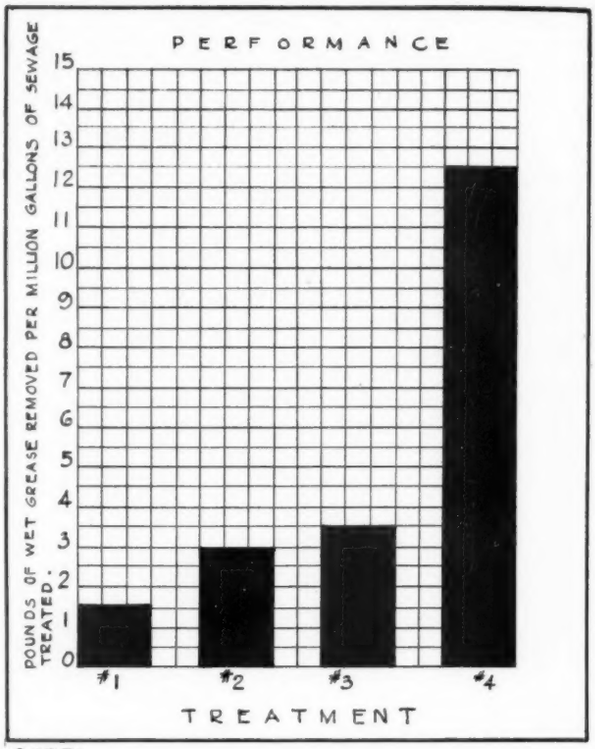
Composite Samples: (Grease content)	Raw Sewage 25 p.p.m.	Primary Effluent 6.0 p.p.m.	% Removal* 76

Date (1937) August	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
26	2.9	0.09	None	4.9
27	2.9	0.09	None	4.3
28	3.0	0.10	None	2.2
29	4.0	0.13	None	1.6
30	2.9	0.09	None	6.1
31	2.6	0.09	None	4.8
Average	3.1	0.10	None	4.0

Composite Samples: (Grease content)	Raw Sewage 19 p.p.m.	Primary Effluent 9.0 p.p.m.	% Removal† 53

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, Aero-Chlorination increased the grease removal 308%.

†On the basis of the analyses of raw sewage and primary effluent an increment of 23% is noted for the removal of grease using Aero-Chlorination over the use of aeration alone.



CODE:
#1. TREATMENT WITHOUT AERATION AND WITHOUT CHLORINE.
#2. AERATION ALONE.
#3. CHLORINATION ALONE.
#4. AERO-CHLORINATION.

Controlled Check Tests—3 Methods

In February, 1938, due to the interruption of plant operations caused by the presence of excessive quantities of gas wastes in the sewage; it was possible to maintain fairly constant operating conditions over a period of time for experimental observations of the performance of Aero-Chlorination. The sewage flow was maintained at 4.0 M.G.D., giving a constant value for detention period and air applied. Chlorine was applied at 2.0 p.p.m. A five-day test was made February 17th to 21st, using treatment without pre-aeration and without chlorine. Another five-day test was made March 4th to 9th, using pre-aeration treatment alone. A third test was made March 16th to 21st, using Aero-Chlorination. The results of these measurements under rather constant conditions are shown in Table III. On the basis of pounds of wet grease removed per million gallons of sewage treated, aeration *alone* increased grease removal 187% over the treatment without aeration and without chlorine; Aero-Chlorination increased the grease removal over aeration alone by 417%; and Aero-Chlorination increased the grease removal 781% over the treatment without aeration and without chlorine. Laboratory analytical results showed 38% grease removal, using treatment without aeration and without chlorine; 50% grease removal, using aeration alone; and 80% grease removal, using Aero-Chlorination.

The grease determinations on the raw sludge and the scum removed are reported for these experimental periods in Table IV.

Chlorination Alone

Experimental measurements were made, using chlorination alone for grease separation on three successive Mondays and three successive Wednesdays during July, 1938. These measurements were made at the suggestion of H. A. Faber of the Chlorine Institute. The results appear in Tables V, VI, and VII. Mondays and Wednesdays were the days selected for these measurements because experience showed that the raw sewage has a maximum grease content on Mondays and an average grease content on Wednesdays. The chlorine dosages were 2.0 p.p.m. The experimental conditions as to the dosing of chlorine and plant operation were parallel to the experimental conditions during the previous measurement periods, using Aero-Chlorination, aeration alone, and the treatment without aeration and without chlorine. The appearance of the grease collecting on the primary tanks were visibly present in smaller quantities than during the treatment using Aero-Chlorination. On the basis of

(*Continued on Page* 201)

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
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"The Only Safe Sewage Is a Sterilized Sewage"

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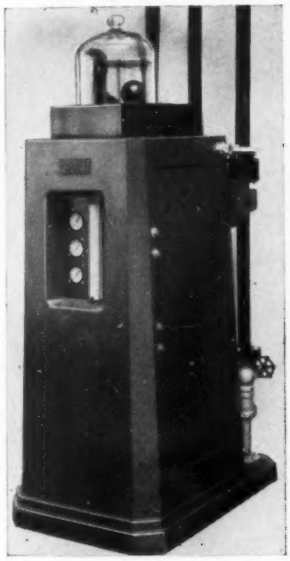
CHLORINATION OF SEWAGE

Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for many years been the versatile and valued aid of the man concerned with sewage disposal.

Chlorination is employed to stabilize raw sewage, control odors along trunk sewers or at treatment plants, protect masonry structures from disintegration, increase efficiency of filter beds and prevent filter ponding, improve sedimentation and remove settleable solids, improve sludge digestion, prevent bulking in activated sludge plants, reduce biochemical oxygen demand and retard putrefaction in the receiving water course, disinfect effluents before discharge and is a necessary adjunct to nearly any process of chemical precipitation.

DISINFECTION

Regardless of what the preliminary process of sewage treatment may be, disinfection of the effluent before discharge has come to be regarded as a necessity. Protection of water supplies, of bathing places and of shellfish propagation beds all require efficient disinfection. That chlorination offers the one practical and effective means of sewage disinfection today is universally acknowledged by sanitarians and public health authorities.



Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 6000 pounds of chlorine per 24 hours.

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Control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also satisfactory in results and economy of operation.

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In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering, as it does, a simple, easily controlled and relatively inexpensive means of supplementing other purification processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has, in many cases, eliminated the necessity for extensive additions to the regular treatment works.

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Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

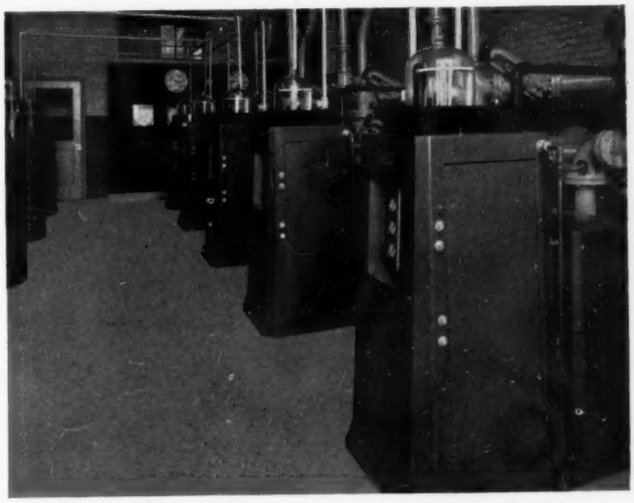
In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnish the necessary equipment. Complete details on request.

W&T field representatives will gladly confer with you about any specific problem relating to the application of chlorine or iron salts in sewage treatment. Technical publications and literature are available on request.

CHLORINE FLOW RECORDERS

Chlorination records form an important log of plant operation and are indisputable evidence that proper application of chlorine was made. Periodic visual inspection will not reveal when equipment may have been temporarily out of service for cylinder change-over, cleaning or any other cause.

The W&T Chlorine Flow Recorders meet the need for continuous automatic flow recording. These Flow Recorders are of two types: the "Direct air transmission type" for continuous recording of chlorine flows, and the electrically operated type which provides indicating, recording and totalizing. The electric type is particularly suitable for use with a battery of chlorinators.



Five W&T Master Visible Vacuum Chlorinators operating at Bird Island Sewage Plant, Buffalo, N. Y.

Panel Mounted Direct Type Recorder with standard Type W&T Visible Vacuum Chlorinator

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pounds of wet grease removed per million gallons of sewage treated, chlorination *alone* increased the grease removal 219% over the treatment without aeration and without chlorine; and chlorination *alone* increased the grease removal 117% over the treatment using aeration *alone*. However, Aero-Chlorination increased the grease removal 371% over the treatment with chlorination alone. These comparisons are made, using the average of the results reported in July, 1938, and the results reported in February and March, 1938. The analytical results showed chlorination alone removed 41% of the grease. The grease analyses of the raw sludge and the grease collected are reported in Table VII.

Improvement in Activated Sludge Noted

The grease content of the activated ("return") sludge has been determined at frequent intervals since Aero-Chlorination has been in use. The grease content of the "return sludge" at the South Plant has been reduced between 64% and 74%. To our mind, this improvement has been due to Aero-Chlorination. These results are shown in Table VIII.

TABLE II

AERO-CHLORINATION VS. AERATION ALONE

Date (1937) Sept.	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
5	3.1	0.09	2.0	6.5
6	3.5	0.11	2.0	15.7
7	2.9	0.10	2.0	17.1
8	2.9	0.10	2.0	12.4
9	2.9	0.10	2.0	16.8
10	3.5	0.11	2.0	18.5
11	4.1	0.13	2.0	11.4
12	4.3	0.14	2.0	5.9
13	3.9	0.12	2.0	18.0
14	4.3	0.13	2.0	14.5
15	5.8	0.18	2.0	15.2
Average	3.7	0.12	2.0	13.8

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	23 p.p.m.	5.0 p.p.m.	78

Date (1937) Sept.	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
20	3.8	0.12	None	4.3
21	3.5	0.11	None	3.4
22	3.5	0.11	None	4.1
23	3.9	0.12	None	2.6
24	3.3	0.10	None	3.5
25	3.2	0.10	None	4.3
26	3.9	0.12	None	2.8
27	3.4	0.10	None	5.7
28	3.4	0.10	None	3.8
29	3.4	0.10	None	2.3
30	3.4	0.10	None	4.4
Average	3.5	0.11	None	3.7

Composite Samples:	Raw Sewage	Primary Effluent	% Removal†
(Grease content)	27 p.p.m.	10.0 p.p.m.	63

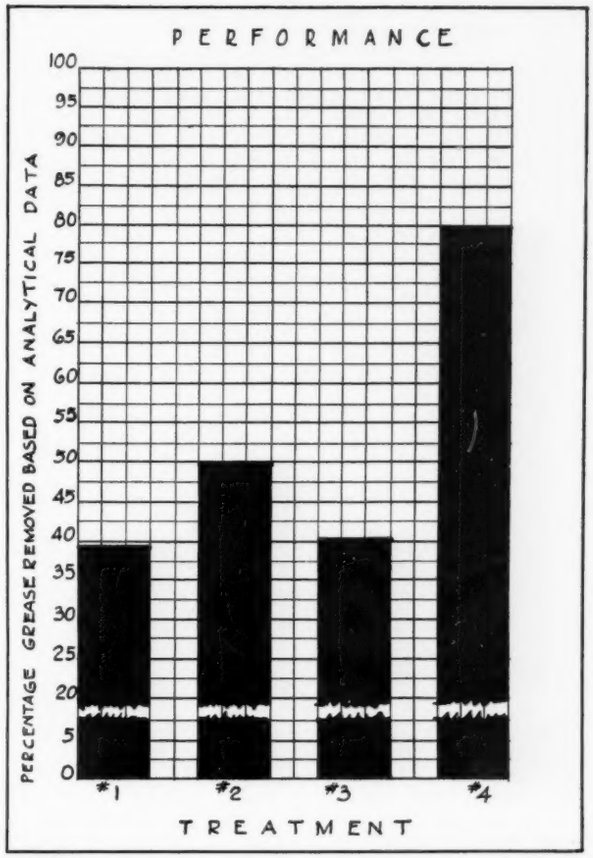
*On the basis of pounds of wet grease removed, per million gallons of sewage treated, Aero-Chlorination increased the grease removal 373%.

†On the basis of the analyses of raw sewage and primary effluent an increment of 15% is noted for the removal of grease using Aero-Chlorination over the use of aeration alone.

TABLE III

THREE METHODS COMPARED

Date (1938) February	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
17 (Thursday)	4.3	None	None	1.3
18 (Friday)	4.3	None	None	1.9
19 (Saturday)	4.3	None	None	0.9
20 (Sunday)	4.3	None	None	2.1
21 (Monday)	4.3	None	None	1.6
Average	4.3	None	None	1.6



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#3. CHLORINATION ALONE.
#4. AERO-CHLORINATION.

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	21 p.p.m.	13.0 p.p.m.	38

Date (1938) March	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
4 (Friday)	4.3	0.14	None	3.1
5 (Saturday)	4.3	0.14	None	2.9
6 (Sunday)	4.3	0.14	None	2.6
7 (Monday)	4.3	0.14	None	2.0
8 (Tuesday)	4.3	0.14	None	3.1
9 (Wednesday)	4.3	0.14	None	4.4
Average	4.3	0.14	None	3.0

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	26 p.p.m.	13.0 p.p.m.	50

Date (1938) March	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
16 (Wednesday)	4.3	0.14	2.0	10.4
17 (Thursday)	4.3	0.14	2.0	13.2
18 (Friday)	4.3	0.14	2.0	12.9
19 (Saturday)	4.3	0.14	2.0	15.3
20 (Sunday)	4.3	0.14	2.0	7.5
21 (Monday)	4.3	0.14	2.0	15.7
Average	4.3	0.14	2.0	12.5

Composite Samples:	Raw Sewage	Primary Effluent	% Removal*
(Grease content)	21 p.p.m.	4.0 p.p.m.	80

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, aeration increased the grease removal 187%. Aero-Chlorination increased grease removal over aeration

alone 417%. Aero-Chlorination increased grease removal 781% over the treatment without aeration and without chlorine.

*On the basis of analyses of raw sewage and primary effluent an increment of 12% is noted for the removal of grease using aeration, over the treatment without aeration and without chlorine. An increment of 30% is noted using Aero-Chlorination over aeration alone. An increment of 42% is noted, using Aero-Chlorination over the treatment without aeration and without chlorine.

TABLE IV
GREASE CONTENT OF PRIMARY SLUDGE AND SCUM

Date 1937—	Treatment	Raw Sludge Pct.	Scum Pits Pct.
Aug. 14-24	Aero-chlorination	27.56*	14.65*
Aug. 26-31	Aeration alone	32.08	12.69
Sept. 5-15	Aero-chlorination	25.67	16.34
Sept. 20-30	Aeration alone	31.17	14.19
1938—			
Feb. 17-21	Without aeration and without chlorine	31.19	10.17
March 4- 9	Aeration alone	30.08	11.19
March 16-21	Aero-chlorination	26.68	12.87

*Grease as determined by Standard Methods of Analysis—A.P.H.A.

TABLE V
PRE-CHLORINATION ALONE

Date (1938) July	Detention (minutes)	Air (Cu. Ft./Gal.)	Chlorine (p.p.m.)	Wet Grease lbs./M.G.
11 (Monday)	4.1	None	2.0	2.7
13 (Wednesday)	3.7	None	2.0	1.9
18 (Monday)	3.4	None	2.0	4.7
20 (Wednesday)	3.4	None	2.0	3.1
25 (Monday)	3.4	None	2.0	4.8
27 (Wednesday)	2.9	None	2.0	4.0
Average	3.5	None	2.0	3.5*
Maximum	4.1	None	2.0	4.8
Minimum	2.9	None	2.0	1.9

*On the basis of pounds of wet grease removed, per million gallons of sewage treated, the treatment using chlorination alone increased the grease removal 219% over the treatment without aeration and without chlorine. The treatment using chlorination alone increased the grease removal 117% over the treatment using aeration alone. These comparisons are made using the average of the results reported in July, 1938, and the results reported in February and March, 1938.

TABLE VI
PRE-CHLORINATION ALONE
(Grease Content in p.p.m.*)

Date (1938) July	Raw Sewage	Primary Effluent	% Grease Removal
11	16	11	31
13	12	7	41
18	21	13	38
20	18	10	44
25	23	11	52
27	17	10	41
Average	18	10	41
Maximum	23	13	52
Minimum	12	7	31

TABLE VII
PRE-CHLORINATION ALONE
(Grease Content—Dry Basis*)

Date (1938) July	Raw Sludge Pct.	Scum Pits Pct.
11	31 63	13 09
13	28.65	12.39
18	35.09	15.37
20	36.11	14.29
25	34.61	14.86
27	33.96	15.10

*By Standard Methods of Analysis—A.P.H.A.

TABLE VIII
QUALITY OF ACTIVATED ("RETURN") SLUDGE

Date	April (1937)	May (1938)	July (1938)	August (1938)
Per cent grease*	21.63	7.78†	6.56†	5.61†
Per cent total solids	0.82	1.02	1.54	1.42
Per cent volatile solids	74.21	77.74	79.32	79.67

*Petroleum ether extraction by Standard Methods.

†Percentage reduction of grease content of Activated ("Return") Sludge:

	Pct.
April, 1937, to May, 1938	64
April, 1937, to July, 1938	70
April, 1937, to August, 1938	74

Discussion and Summary

The grease content of "return sludge" may determine the efficiency of the aeration of sewage sludge mixtures. It is believed that the presence of grease and oils in the "return sludge" and the sewage sludge mixtures do not permit the balancing of rate of oxygen utilization, because the grease and oils spread a protective film on the sewage and sludge particles, making intimate contact, and resulting oxidation slow and incomplete. Also, the absorption of the colloidal matter present in the sewage by the "return sludge" is not complete in the presence of grease and oils, because of this protective film. Aero-Chlorination of the raw sewage for grease removal does reduce the grease content of the sewage and sewage sludge mixtures to a marked degree; thereby, bringing the rate of oxygen utilization into a proper balance. The results at Lancaster show that Aero-Chlorination reduced the grease content of the raw sewage to the extent of 80%.

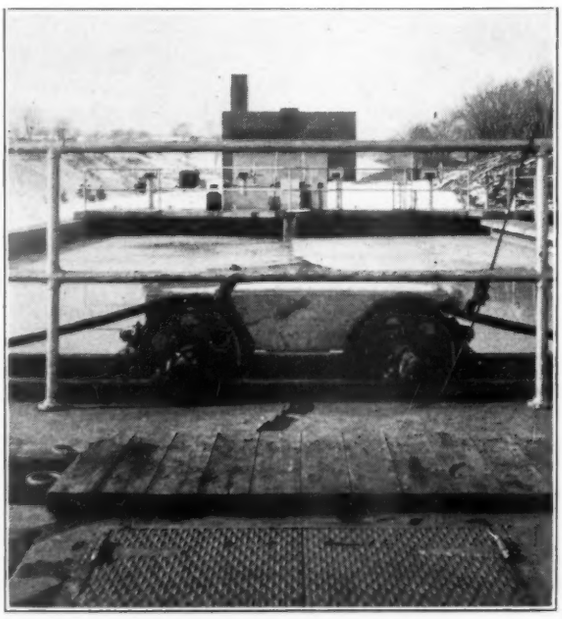
As the result of our tests and study of benefits derived, Aero-Chlorination has been made an operating feature at both of the sewage treatment plants of Lancaster. Since introducing Aero-Chlorination, the South Plant in Lancaster has experienced its first six months of continuously successful operation of the activated sludge phase of treatment. A high quality effluent has been consistently produced for the past six months, with a continuous and pleasing absence of "bulking" troubles.

Acknowledgment is made to L. H. Enslow and H. A. Faber of Chlorine Institute for their helpful suggestions and guidance.

The Department of Streets and Public Improvements is responsible for the management of the Lancaster Sewage Treatment Works. J. A. Taylor, Director; J. H. Shertzer, City Engineer; and E. J. Rhoads, Superintendent.

References:

[1]H. A. Faber, Water Works & Sewerage, 84, 171 (1937).
[2]Keefer & Cromwell, Water Works & Sewerage, 85, 97 (1938).



Primary Sedimentation Units

OPERATING ENGINES ON SEWAGE SLUDGE GAS*

Some Comments on Their Care and Operation

By THOMAS BROWN and GEORGE PRESTON

METHODS of sewage treatment, in which sludge is digested, made possible the production and connection of power producing gas from digesting sludge. In the earlier period of digestion of sewage sludge, the gas generated in the process was considered of no value, and it was burned to waste to prevent obnoxious odors. Then economy demands directed engineers to utilize the sludge gas in heating the sludge in the digestion tanks so as to maintain the required uniform digestion temperature, thereby improving the process of sludge digestion and the quality of digested sludge. In the past few years sludge gas has been put to use also in the generation of power by passing it from the digestion tanks through gas engines—these gas engines driving electric generators or air blowers or raw sewage pumps. To effect further utilization of the heat contained in the sludge gas, the jacket cooling water of the gas engines is passed through heat evchangers which heat the water circulated through the heating coils of the digestion tanks and building spaces. Additional heat is being recovered from the sludge gas by passing the engine exhaust through waste gas boilers to add additional thermal units to the hot water in the heat exchanger.

The Power in Sewage Sludge Gas

Gas from digesting sewage sludge is an excellent fuel for gas engines. It has an average heat value of 600 British thermal units per cubic foot, and values up to 650 or more units are obtained. Its composition is given in general as 64 per cent methane, 30 per cent carbon dioxide, 5 per cent nitrogen, a trace of hydrogen sulphide, and 1 per cent other gases .The gas is produced in a fairly uniform volume at all times in the normal operation of a sewage treatment plant; and possible peak flows or excess quantities may be stored in gas holders.

Generally a municipal sewage treatment plant of proper design can produce one cubic foot of gas per person in 24 hours; but an average conservative figure is three-fifths of a cubic foot. Supposing a sewage treatment plant serves a city of 100,000 people, and the average value of the sludge gas generated is 600 British thermal units per cubic foot, and assuming that three-fifths of a cubic foot of gas is generated per person per day, then the brake horsepower developed is: $(100{,}000 \times 3/5 \times 600)$ $(24 \times 10{,}000)$ or 150 horsepower. If one cubic foot of gas is generated per person per day, the horsepower generated would be 250 for a population of 100,000. If garbage is ground into the sewage, the gas production might be doubled, giving a power production of 500 horsepower per 100,000 population, or 5 per 1,000.

Scrubbing Sludge Gas

If the sludge gas contains an excessive quantity of H_2S or hydrogen sulphide, the pistons and cylinder walls of the engine are likely to be harmed; for the products of combustion, namely, the water and sulphur dioxide (SO_2), unite to form the very corrosive sulphurous acid (H_2SO_3); but any amounts of volatile sulphide are just as objectionable in the engine fuel as is hydrogen sulphide.

If the content of sulphide in sludge gas should exceed 0.07 per cent by volume, or about 50 grains in 100 cubic feet of gas, a gas scrubber should be placed ahead of the gas engine. The sulphur in the state of hydrogen sulphide is removed in the scrubber by passing the sludge gas through a bed of finely divided iron oxide held in wood shavings. The iron oxide reacts with the hydrogen sulphide to form water and sulphide of iron in accordance with the equation $Fe_2O_3 + 3H_2S = Fe_2S_3 + 3H_2O$. The wood shavings serve only as a sponge for the iron, keeping open the mass of iron oxide, so the gas can pass through the scrubber with a minimum of resistance. In order to promote the chemical action between hydrogen sulphide and iron oxide, the temperature of the gas scrubber should be kept above 60 degrees Fahr. Artificial heat may have to be supplied.

The gas scrubber may be built readily by the operating staff of the sewage treatment plant. If 160,000 cubic feet of gas is to be scrubbed per day, containing about 100 grains of hydrogen sulphide in 100 cubic feet of gas, the scrubber should be figured on the following basis: Enough iron sponge should be provided to last about 60 days. There is about 20 pounds of ferric iron in one cubic foot of sponge. Theoretically, 20 pounds or one cubic foot of ferric iron sponge will react with 127,000 grains of hydrogen sulphide. In actual operation, this reaction capacity will be cut to about one-third, or to 40,000 grains of hydrogen sulphide. Figuring 100 grains of hydrogen sulphide in 100 cubic feet of gas, and 160,000 cubic feet of gas per day, the total hydrogen sulphide to be removed in 60 days is 9,600,000 grains. Therefore the amount of iron sponge required is 240 cubic feet. The gas scrubber tanks should be large enough to hold this amount of iron sponge, and in addition there should be at least three inches of space at the bottom of the scrubber, underneath a tray, this space aiding in better distribution of the incoming gas to the sponge bed. The scrubber should be coated inside with a bituminous paint.

The iron sponge can be used over again after regeneration. When it has become exhausted or sulphided in the 60-day period, it is exposed carefully to the air so as to allow the iron sulphide to absorb oxygen, enabling the iron to revert back to its original ferric oxide state according to the equation $2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$. There is so much heat generated in this reaction that there is danger of the iron sponge starting to burn and be destroyed. The rate of heat generation can be controlled by wetting the exhausted iron sponge thoroughly with water, taking it then from the scrubber tank and piling it in the open air. After the sponge has charged from blacw to brown in color, it can be placed back in the scrubber; it should be placed uniformly and tamped lightly as it is placed to fill all space evenly. The iron sponge can be regenerated two or three times in this manner, before it has to be discarded finally.

Engines for Sludge Gas

Gas engines for running on sludge gas are built generally in sizes from 15 to 1,800 horsepower. They are connected direct to electric generators, or to air blowers, or to sewage pumps by way of gearing, or to other mechanical equipment. They are used full or part time, all or part of the installation, as gas becomes available. For running a gas engine full load and full time in spite of insufficient sludge gas supply, city gas can be made available for standby.

The heavy duty slow speed gas engine is preferred to other gas engines. It can run for several years continuously with low cost of maintenance and repairs. In the smaller size of gas engine the valve-in-head type is preferred. By installing a carburetor, gasoline may be used as fuel instead of gas. The gas engine can be expected to have a normal life of 20 years. Repairs will run about $2.00 per year per brake horsepower. The gas engine is required to run almost continually, for if it is shut down, generally considerable electric power must be purchased and a high kilovolt-ampere demand results.

The sludge gas enters the engine by way of a gas mixing valve in which the gas is mixed with atmospheric air in proper proportion. The valve has a function which is similar to that of the carburetor used in gasoline engines, and it contains an air valve and a gas valve, each regulated separately; due to this arrangement the fuel mixture can be changed to suit the changing British thermal unit content of the gas. Just ahead of the gas mixing valve, the gas pressure is reduced to atmospheric pressure by use of a suitable pressure regulator. By installing a gas reservoir between the pressure regulator and the mixing valve, the operator can maintain a constant supply of gas at the atmospheric pressure; and this reservoir should be at least 30 cubic inches in size per horsepower of engine rating.

Generally speaking, at full load the fuel consumption of the gas engine does not exceed 10,000 British thermal units per brake horsepower-hour, which equals 15,000 British thermal units per kilowatt hour. If the sludge gas has a low heat value of 575 British thermal units per cubic foot, a kilowatt-hour generated requires 26.1 cubic feet of gas at full load, 27.5 at 5/6th load, 29.3 at ⅔rd load, and 32.7 at ½ load.

Installations of Gas Engines

Hundreds of installations of gas engines running on sewage sludge gas have been made during the last few years, including

*This article, from *The International Engineer* of May, 1941, so well tells the story of power generation from sludge digestion gas, that we have asked permission to reproduce it.—Ed.

at least 3,500 horsepower at Tallmans Island plant, New York City; 1,820 at the Coney Island plant, New York City; 835 at Peoria, Ill.; 360 at Detroit, Mich.; 300 at Cedar Rapids, Iowa. [See appended list of engine installations. The largest will be that at New York's Jamaica plant, with 3 engines of 1,440 H.P. each—i. e., 4,320 total H.P.—Ed.]

Gas and Air System.—The fuel gas system of the engine consists as a rule of a gas holder or reservoir (which may be a floating cover on the digester tank), a gas meter, a pressure regulator, a mixing valve, and a governor. The governor needs careful attention; its rotating parts must be kept lubricated properly—when the lubricating oil is discharged back to the crank case, attention must be given that the blowby gases are not depositing water in the governor. Keep all flat wearing surfaces of the governor free of depressions so that it continues to respond smoothly and rapidly. Inspect the governor every time the piston is removed.

Draw all intake air through adequate filters; for dust drawn into the engine with the air accelerates the wear of moving parts. All intake air lines should be large which prevents high losses in pressure when the engine is running at full load. The mixiing valves need adjustment and lubrication occasionally. Water should be kept out of the gas piping.

Air Starting and Safety Devices

The air starting system of the gas engine includes air compressor, air reservoir tanks, and air piping. The air compressor should be inspected occasionally and repaired if necessary. See that the condensate drains properly from the air starting tanks and piping. Check blow-off cocks, and float-operated condensate separators on the tanks, periodically to be sure they remove water from the air storage tanks and air lines, and prevent the fouling of spark plugs due to injection of water into the engine cylinder.

The ignition system consists of magnetos, or battery-operated spark coils, timed distributors, high tension distribution wiring and spark plugs. Keep the voltage generated at a minimum to keep the magneto or spark coil in best operating condition; do this by keeping the spark gaps at or near the minimum for production of a good spark. Change or clean spark plugs and re-adjust the gap when the gap increases from the normal 0.025-inch setting to about 0.050 inch. The double electrode plugs are well suited to the gas engine. Spark plug gap adjustment may be required once a month. Clean magneto and distributors once each year and adjust or replace electrodes as needed. Check timing settings against the flywheel markings every time the timing mechanism is dismantled. Inspect high tension wiring for cracks and take precautions against possible cross firing where wires are adjacent to each other.

The engine protective devices generally are instruments actuated by pressure, temperature or mechanical movements, thereby operating electrical switches or relays. These relays and switches ground the magnetos and close the fuel gas valve, so that the engine is shut down. If the gas engine drives an electric generator, there is also a generator breaker which is tripped and the electrical system cleared for normal operation.

Pressure gauges, tachometers, pyrometers and other indicating devices should be kept in good operating condition. All delicate indicating devices and safety devices, and all gauges should be kept mounted on panels which are isolated from the engine so they will not wear due to vibration. The safety devices and gauges should be inspected and checked quite often to make sure they operate properly. Check the protective devices which shut the engine down when the temperature becomes excessive or when the pressure of cooling water or lubricating oil should drop below normal. Also check the overspeed protection device.

Maintenance Schedule

Following a routine maintenance schedule will insure the operation of the gas engine with a minimum of shutdowns. Details of maintenance on the gas engine are affected by the size, speed, operating condition and design of the unit. The operating engineer should have a routine maintenance schedule for each engine to follow throughout the year. He should keep a complete record of all maintenance work on the unit. Such records will help to work out a more reliable maintenance schedule and overhauling schedule as the years pass; and it enables the engineer to keep a closer check on the performance of each engine part. Dated records should be kept on crankshaft allignment, clearance of piston rings, bearing clearance. The operating engineer should take note also of the condition of piston rings, pistons, liners, oil conditions, dimensions and replacements of piston rings, diameters of liners, etc.

Main Crankshaft and Connecting Rod Bearings

After the gas engine has been run for some time, the main crankshaft and connecting rod bearings should be inspected at the rate of once per year. The bearings should be checked for clearance. The main crankshaft bearings must be checked for proper alignment; this should be done after the main bearings are adjusted and whenever the pistons are removed. Any misalignment can be determined by measuring the deflection of the crankshaft flanges when rotating the shaft. Mount a sensitive deflection gauge between the parallel crank faces of the crankshaft and take readings at 90-degree intervals in the shaft rotation.

If the gas engine is run with misaligned main bearings, a repeated flexing of the crankshaft metal occurs and in the end there will be crystallization and failure of the shaft. If the measured deflection of a large gas engine is .003 inches, the bearings should be adjusted. The bearing adjustment can be done by removing and scraping the lower half of the main bearings until the proper alignment has been obtained. To estimate the clearance in bearings, the most satisfactory way is to remove the small shims, reassemble the bearing until it just binds in the shaft, and then reinsert the proper size of shim to provide the correct clearance.

Every two or three years the clearance between the wrist pin and wrist pin bushings should be measured. If there is a thump of pronounced intensity, it indicates that a wrist pin assembly has become defective. In this case press the pin out of the piston, and measure the diameter of both the pin and bushing with a micrometer gauge. If excessive wear has occurred, grind the pins to true circular section and install new bushings of correct diameter.

Cylinders and Pistons

About every six to eight months the piston should be removed from the gas engine so that carbon deposits can be removed from around the rings and so that any rings showing excessive wear can be replaced. Clean the piston and piston rings thoroughly of gumming oil and hard carbon. The oil holes back of the piston grooves should be cleaned. Replace the piston rings on the same piston from which they were removed. Stagger the ring gaps on opposite sides of the piston. Liner packing rings should be checked for tightness after the engine has been reassembled, by placing the water jacket under water pressure and watching for water leaks into the crankcase.

If pistons are operated for a prolonged time with piston rings stuck, the piston and liner may become scuffed or gouged. If there is an indication that the piston rings are not working properly, clean the piston and free the piston rings at the earliest hour possible. When excessive blowby of cylinder gases into the crankcase is noticed, or when there is a marked increase in the consumption of lubricating oil, it is likely that some of the piston rings have become stuck in the piston ring grooves. By removing the piston rings promptly and correcting the condition, excessive wear on pistons, piston rings and cylinder liners resulting from higher temperatures and poor lubrication is stopped or prevented.

When the piston is being cleaned, inspect the piston rings for wear and ring gap. After the piston rings have been placed on the piston, check the clearance between the rings and groove, by use of a feeler gauge. The seat for the piston ring should be square, and there should be no excessive taper in the ring groove, for this may lead to sticking of the rings. If power or compression rings are to be used over again, chamfer them slightly with a file to remove sharp wearing edges. The oil control rings of the scraper ring type should have a relatively small bearing area and also a sharp scraping edge.

It is best, after the head has been taken off and the liner and piston removed, to measure the diameter of the liner in both transverse and lateral direction at three points of the piston stroke. Then make a record of the readings and compute the amount and rate of wear. After a new engine has been run for some time, the average maximum increase in diameter of the liner may amount to from .0004 to .0005 inches in 1,000 hours of operation. Cylinder liners may stand three reborings, after which new ones should be installed. Any rings showing excessive ring gap, lack of tension and an undue reduction in radial thickness should *not* be used again.

Valves Need Checking

Whenever the engine is dismantled, check the air starting valves and the valve motion devices including gears, camshaft, cams, push rods, and valve operating rockers.

Reseat the exhaust and intake valves periodically to be sure

they will work properly. The exhaust valves should be reseated every two to three months, and the intake valves should be reseated every four to six months. If the valve discs and seats have become pitted, they should be placed in a lathe and ground with a carborundum wheel until all pitting is removed; or the pitting may be removed with a cutting wheel.

Small quantities of carbon and dust depositing between valve stems and guides may cause the valve to stick. This occurs most likely after the engine has been shut down. Clean the valve surfaces and inspect them for proper clearance. Excessive clearance of the valve stem will cause the valve to move sideways too much so that it may not close completely over the entire seat; and the valve disc may start to warp in reference to the stem. It is possible that the valve disc has warped already on the stem, and therefore will have to be aligned. If the valve guides have worn too much, cast iron bushings can be inserted to provide again a proper clearance. Hard steel bushing inserts may be obtained for the valve cages, and also replaceable valve seats.

In larger engines the valves should be in removable cages, or they should be installed in some other way which makes them easily removable for inspection and for grinding of valves. The operating staff should keep a stock of removable valve seat inserts.

If the valve does not seat properly, injury may result to the valve and the gas engine will lose power and operate unevenly. After the valves have again been assembled in their cages, the seating surface should be lapped in with a good grinding paste. Later the fit should be checked by using a colored paste, as for example prussian blue. First apply some prussian blue paste to the cage seat. Then wipe to a thin film with a dry cloth. Then place the valve in the cage. Then rotate the valve disc slightly. Then check the disc which should show a continuous ring of blue. If it does not, more grinding is necessary to make a true contact. Smaller valves may be ground completely more economically by the lapping method only.

Having replaced reground valves, the clearance between the valve stem cap and the valve operating mechanism should be adjusted properly. Inspect this clearance quite often for about two days after they have been put in service and adjust whenever necessary; for there may be a change in clearance for a day or two due to the hammering of the valve. It is a good plan to *inspect the valves about once a week* to make sure that a proper clearance is maintained.

Lubrication

Most careful attention should be given to the lubricating oil system consisting of engine sump or oil storage tank, oil pump, oil filter, or screen, oil cooler, oil centrifuge, or purifier, and oil distribution lines. The best quality of oil obtainable for the purpose should be used in the plant. After a new installation has been started, the oil should be checked say weekly for suspended solids, for viscosity, for water, for neutralization number, and also for sulphur content if the gas burned contains an appreciable amount of hydrogen sulphide. An oil changing and oil purification schedule should be worked out from experience to meet engine requirements; and once this has been done, the *oil conditions* may have to be *inspected only about once a month.*

When operating conditions are normal and a batch system of purifying the oil is used, the oil should be removed fully once a month and new or purified oil substituted. The oil tends to build up solids, due to thermal decomposition. Water which forms in the crankcase of the engine from blowby of combustion gases, leads to the forming of oil-water emulsions which are sometimes called sludge. When accumulating in the crankcase, this sludge should be removed completely before any new or purified oil is added to the system. The rate of oil decomposition and the formation of sludge being increased by excessive blowby of the combustion gases, oil inspection and oil changing may be required more frequently if excessive blowby occurs.

The operator should never allow the sludge to accumulate so it will be pumped through the oil circulating system. The oil pump for the main distribution system should be checked frequently to insure the correct discharge pressure. Oil screens installed to remove coarse particles should be cleaned every three or four months.

It is best to remove the water and sludge from the crankcase by using a gear pump with flexible suction hose. Do not wipe the crankcase with rags, for the lint left might be pumped through the oil lines and deposited on the screen, which will result in lower oil pressure in the system.

Oil Cooling and Purifying

The temperature of the oil in the cooler should not exceed 160 degrees Fahr., and water should not be allowed to leak into the oil. There should be thermometers in the oil line before and after the coolers. When the temperature differential for operating the cooler is not sufficient, the cooler should be bypassed and cleaned. The cooler should be cleaned periodically; remove the tube bundle and boil it in a 10 per cent solution of tri-sodium phosphate (which is an emulsifying agent) until the sludge settled in the tube bundle is removed and softened. Then blow the bundle out with compressed air to remove traces of softened material.

The oil in the circulating system should not contain more than 0.75 per cent suspended solids. The solids content can be reduced in a centrifuge to about 0.15 per cent, and the water content to less than 0.1 per cent moisture. For centrifuging, the oil should be heated first to 140 to 160 degrees Fahr., with a relatively low-temperature element. The oil heater should not be of the instantaneous type, for the element in this heater is so hot that there is danger of breaking down the oil, causing carbon deposits around the heater, which insulates the heater and causes it eventually to burn out.

When the engine is dismantled, check the oil distribution lines. Check also the link mechanism of the force feed lubricator for wear and replace worn parts if any. Also check the lubricating pump for rate of discharge.

Waste Heat Equipment

The cooling water should be maintained soft enough to prevent calcium and magnesium salts from depositing on the surface of the water jackets. The engine cooling water jackets should be inspected periodically for scale deposits. If there are heavy deposits, correct the water conditions to prevent further deposits. Excessive deposits overheat engine parts as a result of lowering the heat transfer rate. It is preferable to use a closed system of water cooling; for in the open system using evaporation by cooling tower, deposits are built up. When a closed cooling system is used, the return water to the engines can be kept between 90 and 100 degrees Fahr. and the water discharged from the engine jackets should not exceed 160 degrees Fahr. Periodically check the water pumps, water jackets and cooling facilities of the cooling water system.

All or part of the waste heat from the engine jacket cooling water can be recovered for use in the water heating system of the building spaces and digestion tanks. This heat recovery saves coal or oil fuel which would otherwise be required to supply the heating system. In a four-cycle slow-speed gas engine of about 90-horsepower capacity, for example, operating under full load, the heat content of gas fuel is applied as follows: 25.5 per cent in useful work, 3.5 per cent in radiation, 33.5 per cent in jacket cooling water, 37.5 per cent in exhaust and friction. Practically all of the 33.5 per cent of heat going to the jacket cooling water can be recovered in a hot water heating system.

It is recommended to *have the cooling water enter the engine jacket at between* 110 *and* 130 *degrees Fahr. and have it leave the engine at between* 140 *and* 160 *degrees Fahr.* To effect efficient cooling of the engine, about 3,300 British thermal units must be removed from the engine jacket water per brake horsepower per hour. In passing the engine jacket water through the heating coils of the digester, therefore, this amount of heat must be extracted from them both winter and summer; if not all of this amount of heat can be extracted from the so-called water cooler in the digester, (that is, the digester heating system), part of the jacket water has to be circulated through a separate water cooler, as for example during the summer season, to obtain the required cooling effect.

The heat that can be removed from the jacket water of a 90-horsepower engine under full load is 297,000 British thermal units per hour. For a 30-degree Fahr. temperature rise the amount of jacket cooling water required is 1,190 gallons per hour. Cooling of the water is effected in the digester heating system or in some other way, and a circulating pump of at least 1,190-gallons-per-hour capacity is needed to effect positive circulation of water. There should be a vented surge tank at the high point of the jacket water system, placed just ahead of the circulating pump or between the engine outlet and the cooler. There should be a thermometer at the cold water inlet and at the hot water outlet.

Waste Heat Boiler

In some gas engine installations the exhaust gases are exhausted to the atmosphere by way of exhaust silencers and waste heat boilers. If a waste heat boiler is used to extract enough heat from the exhaust gases to cool them from 900 degrees Fahr., to 300 degrees Fahr., and a high boiler water temperature is desired to guard against possible condensation and corrosion, the jacket cooling water of the engine may be pumped into the

boiler after preheated to 140 degrees Fahr. The waste heat boiler acts as a silencer for the engine, and if there is a by-pass around the waste gas boiler, it should have an exhaust silencer.

The waste heat boiler requires great care in operation. Water must not be permitted to condense on the gas side of the tubes if maintenance costs are to be kept low. Condensate forming on the gas side of the boiler tubes results in rapid corrosion and tube failure. When waste heat or exhaust gas boilers are not in use, they should be disconnected completely, for valves used in exhaust gas lines do not seat tightly and the gases filtering into the boiler corrode the gas side of the tubes due to deposit of condensate.

Condensation of water on the gas side of tubes, due to cold boilers, can be prevented by generating steam in the boiler and converting it to heating uses; or by heating water in the boiler and controlling its flow in such a manner that the temperature of the water will not drop below 180 degrees Fahr. At points where radiated heat will affect the operation of engine devices, the exhaust gas lines should be kept insulated. The heat radiated from the eingine, which is about 3.5 per cent, cannot be transferred to the hot water heating system; this radiation helps cut down the heating load by heating the engine room partially.

The dewpoint, or the temperature at which condensation on the cooling surfaces of the waste heat boiler begins, is about 130 degrees Fahr. As the gas contacts the boiler surface, there is a sudden drop in temperature; therefore the exhaust gases can be cooled only to that temperature where they will leave the boiler without condensation. *The inlet temperature of the boiler water should not be less than* 130 *degrees Fahr.; and a safe minimum temperature of the exhaust gas is* 300 *degrees Fahr.*

If feed water is not available at 130 degrees Fahr., the waste heat boiler may be used to generate low-pressure steam which is passed to an independent tubular heater, the condensate returning to the waste heat boiler generally well above 130 degrees Fahr. Excess sludge gas, that is not used in the gas engine, can be fired in a gas boiler to supplement the waste heat recovery boiler.

Exhaust gases from a 4-cycle gas engine having water-cooled exhaust manifold, have a temperature of 800 to 900 degrees Fahr.; and exhaust gases from a two-cycle gas engine have a temperature of 300 to 500 degrees Fahr. A 90-horsepower four-cycle engine will produce about 1,130 pounds of exhaust gas per hour at full load, from which at least 150,000 British thermal units can be recovered per hour.

SLUDGE GAS ENGINE INSTALLATIONS IN THE UNITED STATES**

Year	Location	No. of Units	Horse-power*	Driving
1926	Plainfield, New Jersey	2	15	Blower
1928	Charlotte, North Carolina	1	225	Blower
	Charlotte, North Carolina	1	75	Pump
1930	Rockville Centre, New York	1	30	Blower
	San Bernardino, California	1	40	Generator
1932	Rockville Centre, New York	1	60	Blower
	Springfield, Illinois	1	180	Blower
1934	Springfield, Illinois	1	157	Bl. & Gen.
1935	Los Angeles County, California	1	200	Pump
	Cedar Rapids, Iowa	1	210	Generator
	Palo Alto, California	1	40	Generator
	Ontario, California	1	40	Blower
	Madison, Wisconsin	1	230	Blower
	Ann Arbor, Michigan	1	120	Blower
	Peoria, Illinois	1	535	Blower
	Peoria, Illinois	1	300	Blower
	Durham, North Carolina	2	150	Generator
	Greencastle, Indiana	1	50	Blower
	Toledo, Ohio	1	300	Pump
	Toledo, Ohio	1	225	Generator
1936-7	New York City, New York—			
	Coney Island	3	300	Generator
	District of Columbia	1	1200	Generator
	Janesville, Wisconsin	1	30	Generator
	Topeka, Kansas	2	180	Blower
	Richmond, Indiana	1	120	Blower
	Edwardsville, Illinois	1	15	Generator
	Sheboygan, Michigan	2	120	Pump
	Green Bay, Wisconsin	1	120	Generator
	Green Bay, Wisconsin	1	90	Generator
	Fort Atkinson, Wisconsin	1	40	Generator
	LaCrosse, Wisconsin	2	90	Generator
	Hutchinson, Kansas	1	90	Generator
	Elmhurst, Illinois	1	30	Generator
	Kokomo, Indiana	1	45	Generator
	Kewanee, Illinois	1	30	Generator
	Wichita, Kansas	1	70	Pump
	Litchfield, Illinois	1	30	Generator
	Dixon, Illinois	1	30	Generator
	Chicago Heights, Illinois	1	125	Blower
	Atlanta, Georgia—			
	Intrenchment Creek	2	120	Generator
	Clayton	2	180	Generator
	Grand Rapids, Michigan	1	50	Generator
	Aurora, Illinois	2	70	Pump
	Madison, Wisconsin	1	230	Generator
	Monroe, Wisconsin	1	30	Generator
1938	New York, New York—			
	Tallmans Island	2	800	Blower
		2	450	Blower
		2	350	Pump
		2	150	Pump
	Columbus, Ohio	3	750	Generator
	Detroit, Michigan	1	364	Generator
	Fort Dodge, Iowa	1	275	Generator
	Lansing, Michigan	1	240	Blower
	Oshkosh, Wisconsin	2	160	Generator
	Albuquerque, New Mexico	1	150	Generator
	Findlay, Ohio	1	90	Blower
	Battle Creek, Michigan	1	50	Pump
	Newcastle, Indiana	1	45	Blower
	Crawfordsville, Indiana	1	44	Blower
	LaPorte, Indiana	1	27	Generator
	Greensboro, South Carolina	2	160	Generator
	Michigan City, Indiana	1	74	Generator
1939-40	Greenville, South Carolina	2	225	Generator
	Springfield, Missouri	2	198	Generator
	Rock Island, Illinois	5	125	Pump
	Rock Island, Illinois	2	75	Pump
	Rock Island, Illinois	1	75	Generator
	Cedar Rapids, Iowa	1	100	Pump
	Belleville, Illinois	1	100	Blower
	Sharon, Pennsylvania	2	80	Generator
	Butler, Pennsylvania	1	80	Generator
	Wausau, Wisconsin	1	75	Generator
	Wausau, Wisconsin	1	50	Generator
	Wausau, Wisconsin	1	50	Pump
	Pueblo, Colorado	3	75	Pump
	Manitowoc, Wisconsin	1	75	Pump
	Manitowoc, Wisconsin	1	35	Pump
	Davenport, Iowa	1	75	Generator
	Davenport, Iowa	1	75	Pump
	Kenosha, Wisconsin	2	75	Pump
	Stevens Point, Wisconsin	1	75	Generator
	Marion, Indiana	2	75	Blower
	Marion, Indiana	1	50	Pump
	Ithaca, New York	1	50	Pump
	Lake Charles, Louisiana	1	50	Blower
	Carlsbad, New Mexico	2	50	Pump
	Metairie, Louisiana	1	50	Blower
	Two Rivers, Wisconsin	1	43	Blower
	Two Rivers, Wisconsin	1	40	Pump
	Escanaba, Michigan	1	40	Generator
	Shawano, Wisconsin	1	35	Generator
	Litchfield, Illinois	1	30	Generator
	Monroe, Michigan	1	25	Pump
	Gary, Indiana	3	175	Pump
	Gary, Indiana	2	300	Blower
	Cleveland, Ohio	2	390	Blower
	Fort Wayne, Indiana	1	450	Blower
	Adrian, Michigan	1	45	Blower
	Peru, Indiana	1	45	Blower
	Pontiac, Michigan	1	150	Blower
	New York City, New York—			
	Jamaica[1]	3	1440	Generator
	Coney Island[1]	3	920	Generator

[1]Not yet installed. *H.P. of each unit. **(Compiled by Ralph E. Fuhrman, Ass't Supt., Sewage Treatment Works, Washington, D. C.)

"Varec" EQUIPMENT

THE VAPOR RECOVERY SYSTEMS CO.

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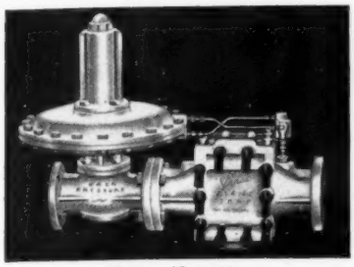


Figure No. 440

THE NEW "VAREC" *Approved* PRESSURE RELIEF AND FLAME TRAP ASSEMBLY

Unit consists of Diaphragm-operated Regulator, Flame Trap, and Thermal Shutoff Valve. Maintains a predetermined back pressure, passing surplus gas to Burner. Stops flame propagation. Patented telescopic flame trap element simplifies inspection and maintenance. Listed by the Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2"	3"	4"	6"
Sh. wt.	125	160	200	260

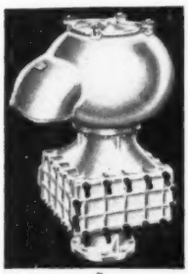


Figure No. 58C

"VAREC" *Approved* PRESSURE RELIEF AND VACUUM BREAKER VALVE WITH FLAME ARRESTER

Installed on digesters and gas holder domes, it affords emergency Pressure and Vacuum Relief and prevents flame entrance from atmospheric disturbances. Equipped with telescopic Flame Arresting element for easy inspection and maintenance. Pure aluminum. Non-corrosive. Listed by the Underwriters' Laboratories for Vent Lines in oil tanks. Sizes 2" to 10".

Sizes	2"	3"	4"	6"
Sh. wt.	70	105	160	225

Figure No. 236

"VAREC" *Approved* WASTE GAS BURNERS

Installed wherever disposal of surplus gas is a problem. Unit has adjustable air intake in the venturi tube, pilot valve adjustable from outside. Long, Heavy cast iron draft stack insures proper draft and complete combustion.

Sizes	2"	3"	4"
Sh. wt.	450	480	500

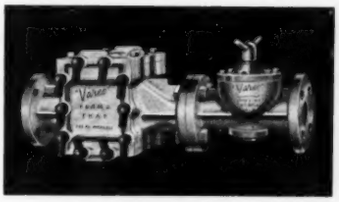


Figure No. 450

"VAREC" *Approved* FLAME TRAP ASSEMBLY

Flame Trap and Thermal Shutoff Valve. Unit self-contained, simple, foolproof. Installed in all gas lines supplying gas utilization equipment. No expensive fitting-up necessary. Arrests flame propagation. Easy inspection and maintenance. Aluminum and stainless steel. Non-corrosive. Flame Trap Element listed by Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2"	3"	4"	6"
Sh. wt.	90	115	150	200

Figure No. 220A

"VAREC" *Approved* MANHOLE COVERS

Installed on digester and gas holder domes, affords quick and easy access. Has square, graphite-impregnated, fire proof gasket. Nonsparking. Gastight.

Sizes	18"	20"
Sh. wt.	100	110

Figure No. 51A

"VAREC" *Approved* FLAME CHECK

Acid resisting. Union type fitting. Positive flame stop for small lines. Has five 40-mesh fire screens. Easy inspection and maintenance.

Sizes	½"	¾"	1"
Sh. wt.	10	10	10

Figure No. 216A

"VAREC" *Approved* MANOMETERS

Single or Triple tube. Open or push-button control types. Accurate. Aluminum housing. Bronze fittings. Pyrex glass. Automatic—Fireproof—Safe. Sizes 6" to 36".

Sizes	9"	12"	15"
Sh. wt.	16	18	20

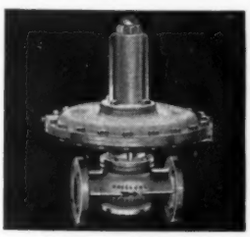


Figure No. 387

"VAREC" *Approved* SENSITIVE PRESSURE (REDUCING) REGULATOR SINGLE PORT

Maintains upstream or downstream pressure to within 0.5" of water of predetermined pressure. Positive Shutoff. Aluminum body. Throttling type inner valve. 18-8 stainless steel trim. Sizes 2" to 6".

Sizes	2"	3"	4"
Sh. wt. ..	100	140	175

Figure No. 211A

"VAREC" *Approved* BACK PRESSURE (REDUCING) CHECK VALVE

Installed in relatively low pressure gas lines. Prevents back-flow through meters. Non-chattering, non-pulsating, non-corrosive, non-sparking.

2"	3"	4"	6"
20	35	70	125

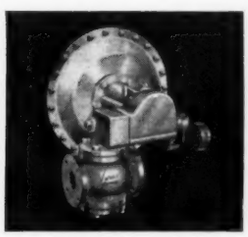


Figure No. 187

"VAREC" *Approved* SUPER SENSITIVE PRESSURE (REDUCING) REGULATOR DOUBLE PORT

Maintains upstream or downstream pressure to within 0.2" of water of predetermined pressure. Standard working parts 18-8 stainless steel with synthetic rubber diaphragm. Non-corrosive. Sizes ¾" to 10".

2"	3"	4"	6"
190	233	260	350

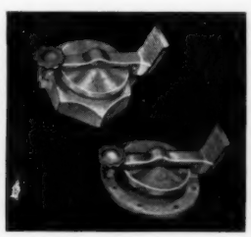


Figure Nos. 48-42A

"VAREC" *Approved* SAMPLING HATCH COVERS

For use on digester domes. Available in several combinations of materials. Non-corrosive, gastight, self-closing, sparkproof. Figure 42A Flanged and Figure 48 Screwed.

4"	6"	8"	10"
12	17	23	27

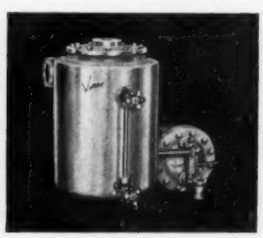


Figure No. 232D

"VAREC" *Approved* SEDIMENT TRAP AND CONDENSATE DRIP TRAP ASSEMBLY

Cast iron construction. 18-8 stainless steel working parts. Hand operated or automatic. Sizes 2"-2½"-3"-4".

SEND FOR THE NEW "VAREC" SEWAGE CATALOG S-3 NOW

GAS HAZARDS*

Methods of Reducing Such at Sewage Treatment Plants

PART I
OPERATION AND MAINTENANCE

Instructions to Operators and Superintendents

Sewers.

a. Solids should never be allowed to accumulate in sewers to give off gas during their decomposition. Frequent inspection, by means of gas detectors, are suggested to determine if explosive or toxic gases are present. Periodic flushing of sewers is also suggested, particularly in sections at flat grade or near dead ends.

b. Inflammable or volatile liquids, such as petroleum products, oil or cleaning solutions, should not be permitted to gain access to the sewers. Garages, dry cleaning establishments, or any building handling volatile or inflammable liquids should be equipped with traps on their sewer connections to intercept such liquids at their source. Frequent inspections of establishments using such products are required to eliminate this all too frequent source of danger. Persuasive letters or the enforcement of a local ordinance or fire code may be used to enforce their exclusion.

c. As much ventilation as possible should be provided. Any complaint relative to odors from sewers must be given careful consideration, the odor traced to its source and eliminated rather than sealing manholes and thus permitting what could easily be an explosive or toxic gas to increase in concentration.

Plant Odors or Sanitation.

a. All pockets which collect solids should be eliminated and ventilation ducts should be maintained at all points where gas might accumulate. The vapors caused by gasoline and similar products are heavy and should be removed from low points of enclosures, preferably at the point of entrance to the plant, while the so-called sewer gas is lighter than air and must be removed at the top of enclosures (incoming sewers must be trapped to provide positive ventilation). Where provided ventilating systems should be used at all times. Where no ducts or fans are provided their installation should be urged. A mixture of air and inflammable gases in ducts is liable to be explosive, therefore, the blower must be of the non-sparking type suitable for such work and the motor must be as approved by the National Board of Fire Underwriters for hazardous atmospheres.

b. Screen chambers, weir chambers, channels and all pockets where sludge or floating solids may accumulate should be flushed clean at least one daily; more often in summer. Any sludge or supernatant liquor spilled during sampling or drawing should not be allowed to stand to give off dangerous gases or odors. Water or clarified effluent under considerable pressure should be available for these purposes.

c. Scum and screenings should be removed daily.

d. Wet wells at treatment plants or outlying pumping stations should be maintained clean enough, at all times to prevent gas formation.

(The above applies to the removal of sources of gas formation which will, by their toxic effect, lower the vitality of the plant personnel if not present in sufficient concentration to become lethal or explosive. The gases present at sewage treatment plants do not always give warning of their presence by the sense of smell.)

Plant Operation.

a. Care must be exercised in drawing sludge or supernatant liquor from digestion tanks with fixed covers. At no time should the liquid level in this type of digester be lowered to a point where the gas is no longer under pressure. The installation and use of gas storage devices cannot be too strongly recommended to compensate for the lowering of liquid level in digesters. Where gas storage units are provided, no attempt should be made to lower digestion tank levels unless sufficient gas is stored to compensate for such lowering of liquid levels; an alarm on gas holders could be installed to warn when the volume of gas is lowered to a predetermined level. Gas holders or floating covers should never be permitted to come to rest (grounded) unless they are to be taken out of service, in which event they should be purged with an inert gas under competent supervision. (Information relative to purging may usually be obtained from local gas engineers.)

b. Sludge levels should be held low enough below gas domes or outlet pipes to prevent the entrance of solids to gas lines. A float operated pump cut-off switch, alarm, or overflows are recommended to keep the scum level(s) below a predetermined point.

c. A daily examination should be made of the liquid levels of all seals. Any liquid displaced or lost by evaporation should be immediately replaced. The use of a non-evaporating anti-freeze solution is recommended.

d. It is suggested that a chart be set up requiring the daily or hourly notation by the operator or assistants of any data pertaining to gas pressures, sludge levels, liquid or sludge to and from the digestors, gas production, attention to seals or any other data relative to the safe handling of sludge gas. A monthly check of conditions of safety and first aid equipment is recommended.

Safety Measures.

a. All gas handling equipment should be maintained gas tight. Joints should be periodically tested by a soap test for leaks.

b. "U" traps, drips or any outlets into enclosed space should not be permitted. Any such outlets found should be eliminated or, if necessary, vented out-of-doors. Under no condition should they be vented to sewers.

c. All enclosed spaces should be properly ventilated (forced ventilation preferred) so that, should leaks in gas handling equipment develop, no toxic or explosive mixture will be built up. Confined spaces frequently used should be constantly ventilated and less frequented enclosures thoroughly ventilated before use.

d. As a precautionary measure, but far from foolproof where explosion hazards exist, all possible sources of ignition should be eliminated—such as:

Flames: Open lights. matches, cigar lighters, fires, blow torches.
Sparks: From tools, lightning, static, electric shorts, motors.
Heated Materials: Heated metals, hot cinders, glowing tobacco.

The judicious use of "No Smoking" signs is recommended where explosion hazards exist. Too liberal use of these warnings tends to minimize their effectiveness. The use of electrical equipment designed for hazardous atmospheres and spark-proof tools is recommended.

e. Electric motors should be permanently and effectively grounded.

f. It is strongly recommended that whenever it becomes necessary to enter any enclosure—such as a digestion tank—in which an oxygen deficiency or an explosive gas or toxic gas is liable to be found, the following precautions be observed: Completely drain any residue of sludge and purge the tank with water and/or an inert gas. Do this with a minimum of manhole disturbance to prevent possible ignition by sparks. Thoroughly ventilate (force draft if possible, never suction unless by means of spark-proof blowers and motors). A workman (or workmen) must never attempt, or be assigned, to enter such an enclosure unless they are equipped with a gas mask of the hose or oxygen helmet type (never canister) and a safety harness (not simply a rope tied around his body) to which is attached a rope strong enough to support his weight, tied at the top and attended by sufficient man power to pull him out if necessary. Maintain communication between the men in the enclosure and those on top. Rubbers or boots should be worn and a great deal of caution observed to prevent sparks from tools or static electricity such as rubbing or striking metal buttons. Masks and safety harnesses must be kept dry and their condition checked frequently. Never attempt to use this equipment without thoroughly testing. All plant personnel should be thoroughly familiar with their use. Only lights that are approved by the National Board of Fire Underwriters for hazardous atmospheres must be used. These same precautions should be observed with the necessary modifications when entering or working in sewer lines. Air and digestion gas must never be mixed in digesters, piping or any gas handling equipment. When digestors or equipment are placed in service or taken out of service, the entire system must be purged with water, an inert gas, or a combination of the two.

g. Gas and oil burners should be installed and used under local

*From the 1940 report of the Committee on Hazards of the N. J. Sewage Works Association.

ordinances or codes and the National Board of Fire Underwriters codes relating to such equipment.

h. A supply of chlorine should be maintained in any process building sufficient for normal demands only. The main supply should be stored in a detached non-combustible building or, if in a room attached to the main building, it shall be of fire-proof construction and separated from the main part of the building by a fire-proof door constructed under the regulations of the National Board of Fire Underwriters. The room or building should be used for no other purpose and should be kept locked at all times to prevent the entrance of unauthorized persons.

i. Two yellow canister masks should be provided for use in chlorinous atmospheres. They should be kept in a dry place which is handy to chlorine storage or use, yet not liable to exposure to chlorine fumes in event of leaks. Every man at the plant should be thoroughly familiar with their use.

Safety Equipment.

The following equipment is recommended for all sewage treatment plants at which sludge gas is collected or burned:

a. A hose mask or oxygen helmet, a safety harness [and two yellow canister masks for use in chlorine gas if included in treatment.)

b. Fire Extinguisher. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Sewage treatment plants should be provided with a suitable instrument for detecting explosive gases and for detecting H_2S. Illuminating gas in sewers may be detected by means of relatively cheap ampoules which indicate the presence of carbon monoxide (CO). A Wolf safety lamp, explosion meter, Orsat apparatuses, or similar equipment are required to test for explosive mixtures. Hydrogen sulphide (H_2S) may be detected by several commercial apparatuses or by a 5% solution of lead acetate.

d. First aid equipment. Personnel employed at sewage treatment plants should have a knowledge of artificial respiration, knowledge of the location of the nearest safety team equipped with an inhalator, and list of doctors and other aids to be called in emergency. (The local gas or electric company usually maintains a safety squad equipped with an inhalator.)

It is suggested that operators and their *assistants* attend first aid meetings and familiarize themselves with first aid and artificial respiration methods. It is suggested that night operators or single operators be required to call the local police station or some other agency hourly and that failure to do this will result in a check-up of the operator's condition by the police. An accident may thus be prevented or a life saved.

e. Manometers or other pressure indicating devices, located at points visible from valves or other controls used to change the levels of digestion tanks, which will indicate gas pressures within the digester and at all other seals. Manometers should be installed in such a manner that the liquid contained therein cannot be blown out to permit the escape of gas into any enclosure.

f. A telephone for use in summoning aid in case of fire, explosion or asphyxiation.

PART II

PLANT DESIGN, PIPING, EQUIPMENT

Sludge Digestion Tanks.

1. *Tanks:*

a. Covered separate sludge digestion tanks shall be provided with means to maintain gas under pressure at all times to allow for reasonable operating fluctuations of liquid or scum levels. Fluctuations in liquid or scum levels will be considered in relation to the volume and moisture content of raw sludge. For domestic sewage, this volume should be from a minimum .3 cubic ft. per capita for plain sedimentation to a minimum of .5 cu. ft. per capita for activated sludge.

b. Covered separate sludge digestion tanks shall be constructed or treated so that they are impervious to gas, and no buildings shall be erected over them.

c. All openings in tanks with fixed covers shall be sealed gas tight. Curtain walls or sampling pipes shall extend at least 6 in. below reasonable operating levels as required in section 1 (a).

d. All closed digestion tanks shall be provided with means for safe disposal of gas as further provided in these recommendations.

2. a. Where gas is collected, domes or similar devices shall be provided at the high point(s) of the digester cover.

b. A safety pressure release with adequate flame protection shall be provided for each collecting dome or floating cover. This device shall be installed to release excess pressure directly from the digester. It shall be designed to operate at a pressure of at least 2 in. of water above maximum operating pressure.

Pipe Lines.

1. *Piping:*

a. Pipe lines to be used for the collection and transmission of digster gas shall be of gas tight construction and shall be pitched with a grade of not less than ½ in. in 15 ft. with drips provided at low points. Consideration should be given to the insulation of exposed lines to prevent freezing of moisture. All piping shall meet the Good Practice Requirements of the National Board of Fire Underwriters.

b. No siphon or "U" taps shall be installed on drips and all automatic drip discharges shall be to a point outside any enclosure. In no case shall this be to any sewer or pipe line.

c. Minimum pipe sizes for gas lines shall be 2½ in. Non-insulated lines exposed to freezing temperature should be double the above capacity. It is suggested that all gas piping be three times its designed capacity.

d. Pipe lines to gas engines shall be suitably protected against flame propagation and excess pressure. All such lines should be independent of all other piping. Sizes and appurtenances shall be determined by the specific engine requirements.

e. Valved by-passes should be provided for all meters.

f. Means should be provided to permit purging all gas handling equipment of sludge gas or air.

g. Means shall be provided to prevent the accumulation of sludge or supernatant liquor in sampling sinks or channels within enclosures.

2. *Valves:*

a. Shut-off valves should be provided for the sub-collection lines for each tank and in the main line before and after the pressure relief and flame traps.

b. Pipe lines or valves shall not be installed permitting the by-passing of flame traps or pressure reliefs.

Equipment.

1. *Pressure Regulation:*

a. Means shall be provided to maintain a minimum working pressure of 2 in. of water in gas piping at the point[s] of consumption.

b. Equipment or devices shall be provided which will confine the fluctuations in working pressure within the gas piping system to a definite limit or range (see also Waste Gas Disposal).

c. Any equipment or device designed for the collection or storage of gas in which excessive pressure may be built up when the flow of gas therefrom is stopped shall be equipped with a device that will permit the escape of gas. It shall discharge at a minimum of 2 in. water pressure over the pressure required in the unit to maintain the designed maximum working pressure within the gas system. Such gas discharges shall not be to any enclosure.

2. *Flame Trap(s) or Arrestors(s):*

a. A flame trap shall be provided close to the service end of all supply pipes, with no connection to a gas consuming unit between the flame trap and source of supply not protected by another flame trap.

b. Flame trap(s) shall be suitably protected from the elements.

c. Where gas engines are to be used, separate flame traps shall be installed on the line (see "Pipe Lines" 1 [d).

3. *pressure Relief(s):*

a. An automatic pressure relief shall be provided suitably protected from the elements.

b. Where gas engines are to be usd, a separate pressure relief shall be installed, of the dry seal type (see "Pipe lines" 1 (d).

4. *Seals and Vents:*

a. Equipment requiring liquid seals shall be provided with indicators clearly showing the liquid levels to be maintained and means shall be provided to introduce an additional supply of sealing liquid.

b. Liquid seals on equipment in locations exposed to freezing temperatures shall be anti-freeze solution.

c. Vents or drip discharges shall be piped to the outside and not to any sewer or pipe line.

5. *Waste Gas Disposal:*

a. A waste gas line shall be provided which will discharge into the atmosphere at a point outside the building at a height sufficiently above ground or surrounding structures to insure proper and adequate dilution, or to a protected burner.

b. The excess gas line shall be free of valves or other possible obstructions.

6. *Waste Gas Burners:*

a. Waste gas burners shall be designed and installed so as to maintain a flame in high winds or rain and shall be provided with a flame trap and a pilot from the outlet side of the main flame trap or an individual flame trap.

b. Waste gas burners shall not be placed nearer than forty (40) ft. from digestion tanks or twenty [20) ft. from any building. They may, however, be placed at least five (5) ft. above flat roofs or two (2) ft. above ridges of gable roofs of buildings provided they are at least fifteen (15) ft. from any higher story or any adjacent building and the roof is of fire-proof construction.

7. *Gas Meters:*

The installation of gas meters is recommended to measure the production and consumption of gas.

8. *Pressure Gages:*

a. A gage, or gages, to show in inches of water (or equivalent) the gas pressure in the digestion tank shall be provided and located so as to be visible at the points of control for the withdrawal of sludge and supernatant liquor.

b. Pressure gages in the line(s) before and after the flame traps and at points of gas utilization are desirable.

c. Manometers shall be designed to prevent escape of gas into any enclosure caused by a blow out of liquid.

9. *Boilers:*

a. Gas and oil burners should be installed and used under local ordinances or codes and the National Boar of Fire Underwriters codes relating to such equipment.

b. Flues from gas heaters shall be separate from building heating plant shimney and shall be carried above roof a minimum distance of three [3) ft. above flat roofs or two (2) ft. above ridge of gable roofs, or if near chimneys an additional height of at least eighteen (18) in. above adjacent chimneys.

c. Siphonage or other type of ventilators on top of flues that will prevent backdraft are recommended.

10. *Gas Holders:*

a. Where gas holders are installed to compensate for differences in liquid or scum elvations in digestion tanks, they should have capacities as required under "Sludge Digestion Tanks 1 (a)." They shall be connected so that any lowering of liquid level in the digester is compensated for by a flow of gas from the holder to the digester. Alarms or cut-off switches are recommended to maintain the volume of gas in the holder above a predetermined minimum.

b. The capacities of gas holders to be used in conection with gas engines shall be considered in relation to the engine requirements.

c. Gas holders of the high pressure type shall include a balancing suction tank and automatic regulators to pump controls.

11. *Ventilation:*

a. Forced draft ventilation shall be provided with outlets at or near the sewage level in enclosed screen chambers, covered sedimentation tanks, and at all points where either heavy or light gas may accumulate. Ventilation by suction is recommended.

b. Ventilating fans shall be of the non-sparking type suitable for hazardous atmospheres. Motors shall be so mounted that no contact is made with the air in ducts or blowers and shall be constructed as approved by the National Board of Fire Underwriters for hazardous atmospheres. Electric motors shall be permanently and effectively grounded.

12. *Housing of Equipment:*

a. Where installed in buildings, heating equipment, flame traps, pressure reliefs, gas meters, etc., shall be located in a separate building or room. The room shall be cut off from the rest of the building by fire-proof walls as approved by the National Board of Fire Underwriters. The entrance to the room or building shall be from the outside and through a door designed to swing outward.

b. The floor of the building or room housing such equipment shall not be located below the ground surface and, if over or under other parts of a building, shall be of gas-proof construction.

c. The room or building shall be ventilated at both the floor and ceiling.

d. The walls of the building or room shall have liberal glass area consisting of thin glass sash. Where, because of exposure, it is necessary to use wired glass, sash shall be so hung that they will readily swing out in case of an explosion. Such sash shall not be secured.

e. All electric wiring, including lights and switches, shall be as approved by the National Board of Fire Underwriters.

f. The use of individual gas heaters is not recommended to burn sludge digestion tank gas.

13. *Safety Equipment:*

a. A hose mask or oxygen helmet and safety harness shall be provided.

b. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Gas detectors for inflammable or toxic gases are recommended.

d. A telephone is recommended.

14. *Chlorine:*

a. A separate building or room of fire-proof construction as approved by the regulations of the National Board of Fire Underwriters shall be provided for chlorine storage. It shall be designed solely for chlorine storage, adequately ventilated and its door provided with a lock.

b. Gas masks for use in chlorinous atmospheres are recommended.

Edward F. Shissler, *Chairman*, Leigh Morril, *Secretary*
R. M. Cadman, I. R. Riker.

Limits of Flammability of Gas-Air Mixtures*

THE above table gives the approximate limits of flammability of gasses when admixed with air at ordinary temperatures and approximately atmospheric pressure. The list includes those gases found in sewers and at sewage treatment plants. The figures represent % by volume of the respetcive gasses in the air-gas mixture. The "Lower Limit" is that below which explosions *will not* occur; the "Upper Limit" is that below which flame propogation *will* be experienced, if not explosion; and above which the ratio of oxygen to gas is not sufficient to support burning or flame propogation in a closed tube or vessel.

Courtesy of The Vapor Recovery Systems Co.

	Lower Limit By Volume	Higher Limit By Volume
Ammonia	14.8	79.0
Methane (static)	4.3	14.0
Methane (turbulent)	5.0	15.0
Hydrogen	4.1	74 0
Hydrogen Sulphide	4.3	46.0
Carbon Monoxide	12.5	74.0
Water Gas	9.0	55.0
Natural Gas	4.8	13.5
Illuminating Gas	5.3	31.0
Blast Furnace Gas	35-37	65.0
Methane and Hydrogen Sulphine	4.1	71.5
Methane and Nitrogen	5.8	12.8

CORROSION OF SLUDGE DIGESTER PARTS

Corrected by Application of Cathodic Protection

By G. A. PARKES
Ass't Engineer, Department of Public Works
Los Angeles, California

AFTER fourteen months of service it was a decided shock to find that the metal parts within the sludge digestion tanks of the Terminal Island Treatment Works of Los Angeles had suffered marked corrosion. Almost every metal part that had been in contact with sludge, scum or supernatent liquor had suffered attack. Pitting had penetrated to a depth of five-sixteenths of an inch in a few places, while in many places extensive areas showed corrosion varying from one thirty-second to one-eighth of an inch below the original surface.

Certain peculiarities were noticed. One side of a structural member might be severely corroded while the other side of the same member remained entirely untouched. The hot water coils of galvanized wrought iron were badly attacked in some places and in others the original galvanizing was intact. The hooks supporting the coils were likewise affected.

No one part of the tank was affected more than another and all metal parts in the tank were affected. It so happened that all these parts were of iron or steel and no brass, aluminum or other non-ferrous metals were present. Interestingly, the galvanized wrought iron pipe had been attacked as badly as the structural steel of the sludge stirring mechanism. The digester in question is a single stage, fixed cover, heated, concrete tank, 75 feet in diameter by 27 feet sidewall height.

The sewage treated at the Terminal Island plant averages about 3.0 million gallons daily and includes a considerable industrial load from two fish canneries. Solids and oil in the cannery waste caused a thick tenacious scum to form in the digester.

What the Inspection Revealed

To examine conditions, it was decided to shut the plant down and drain the digester and make a thorough inspection.

On entering the tank for inspection, while it was being drained, the writer felt several manhole steps bend under his feet. Later, it was found that these steps, originally ¾ inch in diameter, were eaten nearly through. On the other hand, it was of peculiar interest that some of the steps were as good as new.

The sludge was transferred to the clarifier and decantation tanks for storage. This saving of sludge proved to be a fortunate thing, for it not only provided a sufficiency of seed sludge when the digester was again placed in operation, but it also supplied the real clue which led to the final solution of the corrosion problem at Terminal Island.

As soon as the tank was clean, and safe to enter without wearing hose masks, the surprising conditions were discovered. Out of all the mass of facts observed and noted only two observations seemed to be favorable. There was no indication that the concrete of the tank itself was damaged, nor was there any evidence that the steel reinforcement embedded in the concrete had been attacked.

This last fact was a good deal of a puzzle, but at the same time it was a Godsend, for if the reinforcement had been corroded, the concrete would have been cracked beyond repair and the whole tank a total loss. The effects of the corrosion were so serious and had taken place in so short a time, that it was evident that unless the cause were discovered and eliminated, the entire mechanism and perhaps also the tank would soon be destroyed.

Causes Considered

Several theories were advanced as to the cause of the corrosion, none of which proved of any help in the solution of the problem. Inquiries at the time failed to reveal any similar conditions elsewhere, although some cases of corrosion in digesters have been reported more recently.

The sludge was not altogether normal, due to the presence of the fish waste already mentioned, although the pH had been consistently above 7.0. This fact seemed to eliminate the possibility of acid corrosion.

Later investigation showed that the sludge and scum were high in either sludge matter, probably high in sulphides and extremely high in chlorides. The latter, which was due to large quantities of sea water and brine used by the fish canneries, has sometimes amounted to 2,000 ppm. in the raw sewage entering the plant during the sardine packing season and for some unknown reason is concentrated to as high as 5,000 ppm. in the sludge in the digester. These figures vary widely, the average being less than one-half the above. These facts, particularly the chlorides, undoubtedly had a bearing on the case, but were not known at the time the corrosion was discovered.

In the meantime, while the theorizing was going on, reconstruction work was under way in the digester under the direction of the writer. The original scum breaker was removed and a short, stiff truss was installed with vertical angles which meshed with stationary combs bolted to the roof. Figures I and II show some stages of this work. The hooks, which supported the hot water coils, being no longer safe, a system of wooden racks of redwood lumber was devised by the writer. These racks were held together by birch dowels, as wood is known to be very resistant to digestion processes. Part of these wooden pipe racks can be seen in Figure II.

The Investigations

The suggestion was finally made that the corrosion was similar to that caused by galvanic action or by electrolysis, the last being usually caused by stray electric currents. As this theory seemed to be more reasonable than most of those advanced, investigations were undertaken to find the source of such currents. These studies were made while the repairs were going on.

Alternating current is used for lighting the plant and for power to operate the digester mechanism, but all previous research has shown that alternating current is rarely, if ever, a cause of electrolytic corrosion to any serious degree.

A well known expert on electrolysis inspected the plant and gave the opinion that the corrosion was caused by stray direct currents from street railway operation. It was found, however, that there are no electric railways on the island and that there is no direct current produced or used in any appreciable amount. Furthermore, the only possible path by which such current could enter the plant was by the city water main. The water service pipe was disconnected and it was found that a higher electrical potential existed in the plant system than in the water main, indicating that the source of current was *inside* the plant rather than outside of it. This proved an important discovery.

At this time, the services of Mr. Otto Wiemer, Electrical Engineer of the Department of Building & Safety, of the city of Los Angeles, were obtained, who, with the writer, made an extensive series of investigations as to the source of the electric current which was apparently being generated within the plant.

A complete description of all the investigations would be far too lengthy to be included in this article. Many experiments and unsuccessful attempts were made to correlate the electrical potentials which were found to exist between the different parts of the plant. Various types of grounds were used, chromium rods, copper sulphate sponges, and what not. But the chief difficulty was the inability, with these methods, to reproduce any observed reading on two successive days.

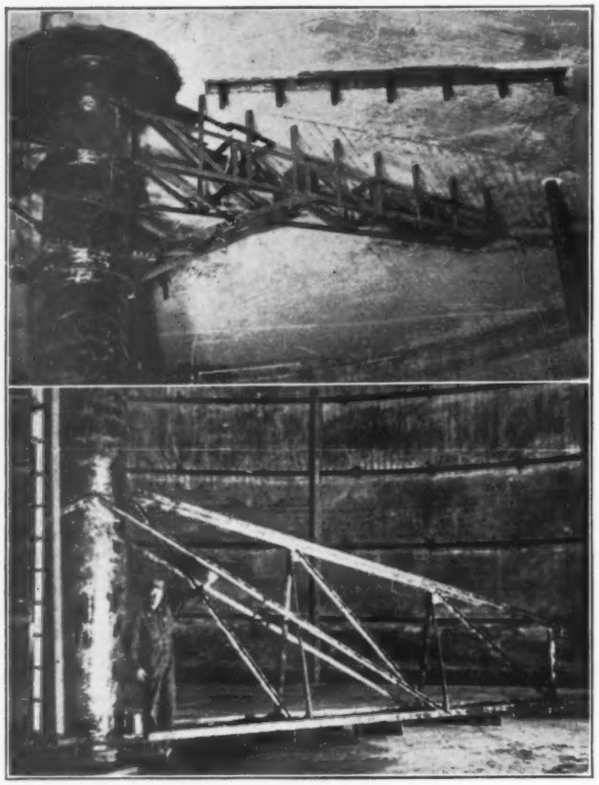
The "Bench-Mark" Method

Finally a method was decided upon, which for want of a better name was called the "bench-mark" method. This simply consisted of using one point (a conveniently situated water faucet), as a reference point and observing the potentials—i. e., voltages, of all other points in the plant, with reference to this one point. Several hundred readings were made and recorded showing values, positive or negative, with reference to our "bench-mark." It was found that these readings could nearly always be checked quite closely when the work was repeated on subsequent days.

The equipment used for this work consisted of a very sensitive voltammeter, known as a Rawson Junior "Multi-meter," with full scale readings in decade arrangements from as low as two millivolts to one thousand volts and from 0.1 milliampere to one ampere. Several hundred feet of No. 12 rubber-covered wire on a spool, and numerous clips and points for making connections, completed the outfit.

The Clarifier Proves a Giant Galvanic Cell

It has already been stated that during the reconstruction of the digester, the plant had been shut down and the contents of the



Figs. I and II—Digester Interior

Showing mechanism protected with Bitumastic coating, which reduces current requirement and enhances efficiency in Cathodic protection. (Above)—New scum-breaker, with stationary combs bolted to roof. (Below)—Sludge-sweep mechanism and heating coils on tank walls, both protected with "Bitumastic" enamel.

digester transferred to the clarifier and decantation tanks for storage.

It so happened that most of the first readings were made at scattered points throughout the plant and showed only small voltages above or below the "bench-mark." However, finally, a series of increasing potentials noted led to the clarifier, in which digested sludge was stored. Here a difference of four hundred millivolts (0.4 volts) was found between various parts of the clarifier piping and steel work and our "bench-mark." Similar but lower differences existed between parts of the decantation tanks (also filled with sludge) and the "bench-mark."

The investigation was continued and readings made of differences of potential between the "bench-mark" and several hundred points throughout the plant. These points included hot and cold water systems, sludge pipes, electrical conduits, exposed metal parts in tanks, reinforcing steel in various structures and even hand rails and the wire fence enclosing the plant property.

The readings varied over a wide range, positive or negative, to the "bench-mark." But, from a study of all the readings, it became evident that greatest differences of potential existed between the point of reference and those tanks in which the digesting sludge was stored.

Figure III—A table which appears later—reveals the method of keeping the notes.

The only possible inference which could be drawn from these observations was that in some manner, not entirely clear, the said tanks were acting as huge galvanic wet cells and were actually producing direct current. This current was leaking out through many inter-connected paths throughout the plant and was returning through other paths to complete the electrical circuit.

In applying this "wet battery" theory to the digester, which was still undergoing repairs, it was possible to conceive that the corrosion already described could ahve been caused in this way, provided the corroded parts were "anodic" (positive), and some other parts were "cathodic,"—i. e., negative. In galvanic action, current flow is always from the positive to the negative electrode.

It is well known that when two dissimilar metals are immersed in an electrolyte and connected externally, a current will flow from one electrode to the other and that one of the electrodes (the anode) will pass into ionic solution in the process. Such action is known as galvanic action. It is also well known that it is not necessary to have entirely dissimilar metals, such as copper and zinc, for such a condition to exist. Even electrodes of the same material, such as iron, which by reason of difference in area, or surface condition or partial protection, will behave in the same manner and one of the electrodes will be eaten away.

Laboratory and Model Studies

A number of tests made in the laboratory, using numerous samples of iron and steel, and sludge liquor for electrolyte, proved that electrolytic corrosion could take place. One test was made with two small grids of black iron bailing wire of exactly the same size and shape. One grid was used bare and the other was cast in a plaque of concrete, one inch thick. Both grids were immersed in sludge liquor and showed a definite flow of current when externally connected. Diagram No. 1 shows the well known principle of the galvanic cell and the close relation to our sludge cell, which behaved in a similar manner.

FIG. III—TYPICAL NOTES OF POTENTIAL DIFFERENCES USING THE "BENCH-MARK" METHOD

Location	Potential* Millivolts
6-in. C. I. pipe to east sludge beds	+ 21
2-in. W. I. pipe—sprinkler system	+ 3
Reinforcing steel—digester wall	+ 36
Wire fence—south property line	— 13
Telephone conduit—office	+ 18
Hand rail—pump house	+ 42
Discharge—high pressure wash pump	+150
4-in. C. I. suction—effluent wash at clarifier	+400**
Clarifier sludge outlet pipe	+385**
4-in. C. I. gas pipe at regulator pit	+ 32
Decanter tank—sample pipe	+108**
Decanter tank—float guide	+210**
Gas holder frame	+ 32
Digester—supernatant overflow pipe at ground line	+ 18
Reinforcing steel—venturi flume structure	+ 11

*Potential expressed in millivolts between the water-faucet "bench-mark" and the equipment listed, + meaning flow away from the unit listed.

**Digester sludge was stored in these tanks.

A model was then constructed to simulate, in principle, the construction of the digester. The model was made of concrete, sixteen inches in diameter and twelve inches high, with walls and bottom two inches thick. A cage of bailing wire was cast in the walls and bottom to represent the reinforcing steel, while a coil of wire supported inside the "pot" and in contact with the cage represented the hot water coils. The sludge stirring mechanism was represented by a grid of wire supported in the middle. Several wires were brought out for electrical connections and the "pot" was filled with sludge liquor.

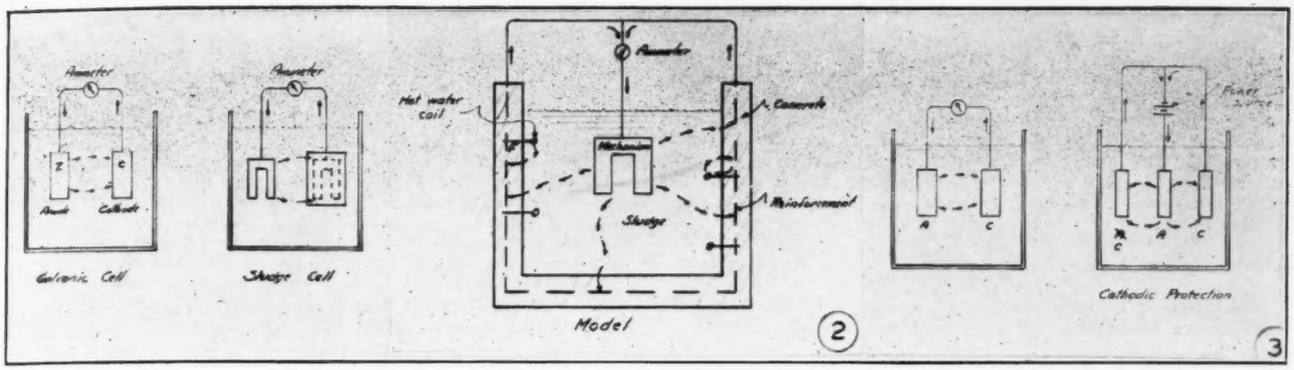
Diagram No. 2 shows the arrangement of "pot" model. The parts indicated as "reinforcement," "hot water coil" and "mechanism" were baling wire.

Readings made with the sensitive voltmeter showed that current flowed through the instrument from the wire cage which was encased in concrete to the grid which was suspended in the liquor. This proved that the "pot" was acting as a battery and that a self-generated current passed from the wire grid (anode) through the liquor electrolyte to the wire cage in concrete, which was the cathode. The current passed back through an external wire to the anode, thus completing the circuit. Current also probably flowed from the wire which represented the hot water coil to the wire cage, and back to the coil through the supporting wire, although this could not be proven.

However, after exposure for about three weeks, with the cage externally connected to the grid, a noticeable amount of corrosion was found to have occurred in wire representing the hot water coil, as well as in the grid representing the sludge and scum mechanism.

It was suggested that a possible source of electric current might be the maze of piping which connects the various parts of the plant. These pipes of various materials, are for the most part, buried in the damp, salty sand of the plant site and may at times be in brackish ground water.

This theory was based on the well known fact that pipes passing through varying types of soils are subject to electrolytic corrosion. In this case, the pipes buried in the ground would be cathodic while the other ends, being in contact with the sludge in the digester, would be anodic and, therefore, would be corroded. However, the experiments with the "pot" model, already mentioned, proved that current was produced when the model



Diagrams 1-2-3—*Revealing Similarity Between a Simple Galvanic Cell and That Produced With Electrodes in Sludge Liquor, as the Electrolyte*

(1) *Galvanic Cell and Sludge Cells.* (2) *Concrete Model of Sludge Digester Used in Study of Current Flow Resulting From Galvanic Action.* (3) *The Simple Galvanic Cell After the Introduction of a Sacrificial Anode Between the Two Electrodes and Reversal of Current Flow. Thereby, What Was Originally the Anode Becomes Another Cathode, Thus Producing So-called "Cathodic Protection" When the Imposed Current Reverses the Flow of Ions.*

was standing on a bench and *not* in contact with the ground—i. e., was in nowise grounded.

A test was made to simulate conditions to test the above theory. The "pot," partly buried in the sand, was connected to a quantity of junk iron buried nearby. This sand was well-soaked with ground water and conditions of current flow noted. It was found that a small current, probably not over 15 per cent of the total, was produced by the buried iron and the remainder (85 per cent or better) was produced inside the "pot." It was concluded that, due to the smaller relative area and to faulty electrical contact, the piping system of the plant would deliver but a negligible amount of current to the digester.

The Digester Studied

After a very careful consideration of all the foregoing evidence, it was concluded that the corrosion which had occurred in the digester had been caused by an electrolysis due to a self-generated or galvanic current within the digester itself.

Further investigation was made to find the cause of the "spotty" condition of the corrosion in the digester, particularly as to why some of the manhole steps and pipe hangers were severely attacked and some were not. It was found by passing a small electric current from a flashlight battery through the various parts, that the steps and hooks which were corroded were apparently in good contact with the reinforcing steel in the concrete walls of the tank, while those which were not corroded were in poor contact or not in contact at all. This poor contact would prevent the completion of an electrical circuit without which electrolytic (galvanic) corrosion could not occur.

It could only be assumed that the "spotty" conditions of structural steel members and some portions of the piping was caused by the fact that some of the original bituminous paint coating adhered to some areas and caused a concentration of current on the unprotected areas.

Considering the digester as a whole, the electrolytic conditions which could have caused the corrosion were now considered as being somewhat as follows:

The hot water pipes, being directly exposed to the sludge and therefore, by reason of their environment, dissimilar from the steel of the reinforcement, acted as anodes. Current flowed through the sludge electrolyte to the cathodic reinforcing steel embedded in the damp concrete and thence back to the pipes through the supporting hooks which were in contact with the steel. The pipes, being anodic, were eaten away. (By referring to Diagram No. 2 and imagining that the external lines leading to the ammeter represent the massive steel and concrete roof structure, the reader will have less difficulty in following the writer's explanation.)

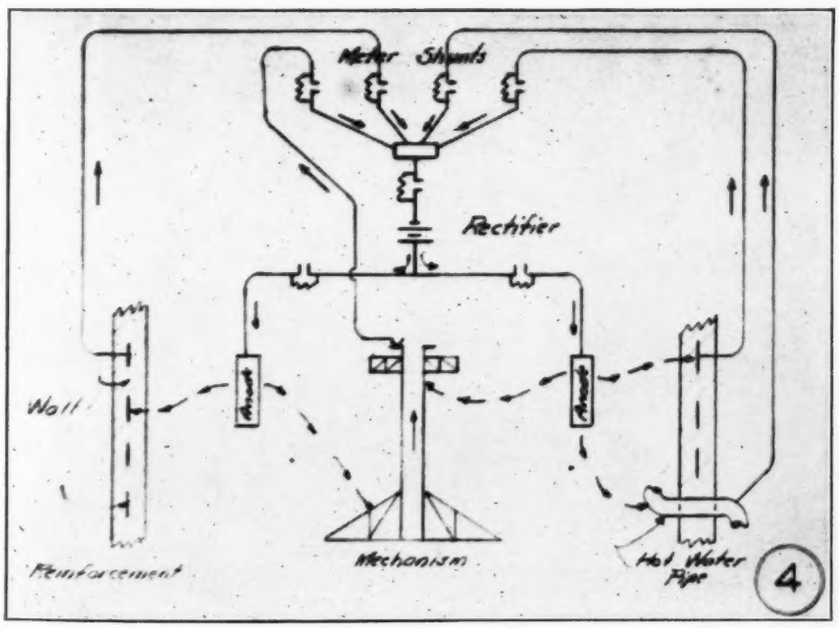


Diagram 4—*Cathodic Protection Diagram as Applied to Sludge Digesters*
Sketch Reveals Arrangement of Sacrificial Anodes and Reversed Current Flow Onto Metal Parts of Digester to Be Protected, and Its Return Through Metering Shunts. The Imposed Current Follows the Path of Least Resistance, Which Is to Exposed Metal Where Corrosion Is Most Active and Protection Most Needed.

In the case of the sludge stirring mechanism, the structural steel members were also anodic and current passed through the sludge to the reinforcing steel. This steel, being in contact with the roof of the tank, itself of reinforced concrete with steel beams, passed the current to the rotating sludge mechanism through the driving machinery and thrust bearings, thus completing the circuit. Here again, the steel members of the stirring mechanism, being anodic, were corroded.

While the data obtained in the investigations did not definitely prove that the corrosion had been caused in the manner above stated, it seemed that all of the facts fitted the theory and that no other theory fitted all of the facts. It was therefore decided to proceed to devise protective measures on this basis.

Protective Measures Adopted

At first, an effort to insulate the various parts was considered. This would have been extremely difficult, if not impossible, and at best would have been unreliable, due to the many possible paths for the flow of current. It could not have been accomplished without extensive reconstruction of the tank.

Protective Coating

It was decided to sand blast all of the exposed metal in the tank and to cover the parts with a good bituminous coating. After sand blasting, the parts were given a prime coat of Wailes-Dove-Hermiston Corporation's "Bitumastic" solution, followed by two

coats of hot "Bitumastic" enamel, mopped on. This material produces a thick, rather rough and brittle coating but when properly applied gives good protection. (See Figures I and II.) A coating, however, on such surfaces, cannot be applied so as to give 100 per cent coverage and it was realized that additional protection by other means would be required. In fact it was quite likely that a 99.9 per cent covering would be worse than no covering at all. For if the cause of the corrosion was to continue unabated, all the attack would be concentrated on the uncovered areas. This would result in the prompt and complete failure of the unprotected parts.

Cathodic Protection Adopted

After considerable study and inquiry, it was decided to test the method of anti-galvanic action known as "cathodic protection" which has for some time been used to protect oil, gas and water pipe lines from external soil corrosion; and more recently applied to water towers and tanks for stopping internal corrosion.

This method of protection has as its basis the fact that if a metallic surface, which would otherwise be anodic and therefore subject to electrolytic corrosion, be made cathodic by externally applied direct current, that surface cannot be corroded and is therefore protected.

Diagram No. 3 illustrates the principle of cathodic protection. At the left is a simple galvanic cell, identical to Diagram No. 1. As shown, the anode would be eaten away while the cathode is unaffected. However, if another plate is inserted into the cell (Diagram 3—right) and connected to a power source externally as shown, then the new plate becomes the anode and both of the original plates become cathodes. The former anode is now cathodic and is no longer corroded.

In this system, two things are apparent. The potential (voltage) of the new power source must be greater than the natural potential of the cell itself, which is usually small. Also the new anode would eventually be destroyed—sacrificed to save the other surfaces. Such anodes are known as "sacrificial" anodes.

In the case of pipe lines, the pipe to be protected is connected by wire to the negative side of some direct current power source, such as a motor generator set or a rectifier unit, the positive side of which is connected to a so-called "sacrificial" anode, usually some sort of junk iron. The anode is buried in the ground at some distance from the pipe. Current coming from the power source passes first by wire to the anode, then through the ground to the pipe, returning by wire to the source. The pipe thus becomes negative to the anode and the latter is destroyed instead of the pipe. Hence the name "sacrificial." The cost of replacing the junk iron anodes is small, as is also the cost of power required.

In protecting the interior walls of steel tanks the tank is made cathodic and dc. current flows from the anode suspended in the tank, through the water and to the tank walls.

It must be understood that, while theoretically such a method should provide complete protection, due to the numerous uncontrollable factors encountered in the field the conditions causing corrosion can only be mitigated to a large extent. In any case, the life of the pipe line or tank is greatly extended and the cost of protection is well worth while.

Application and Arrangements

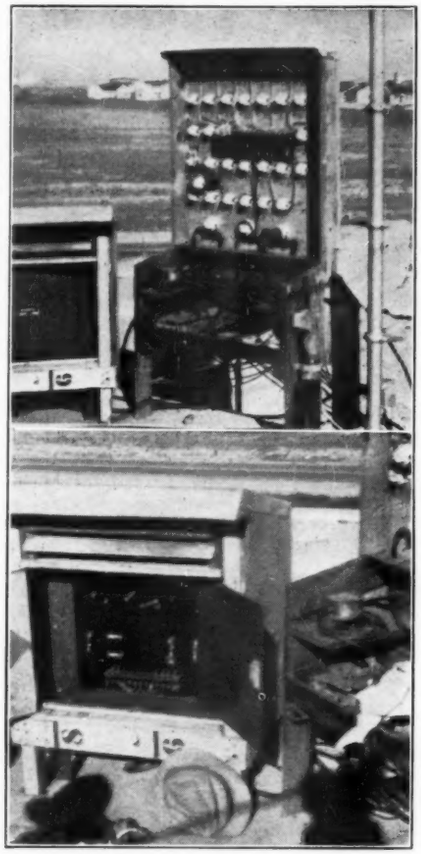
While there was no precedent to be followed in the case of a sewage digester, it was felt that the cathodic-protection scheme could be used to advantage, and would reduce, if not entirely prevent, the necessity of costly replacements in the near future.

Two anodes were provided, one being hung through each of the two manholes in the roof of the digester. These anodes were steel plates eight feet long, two feet wide, and one-quarter inch thick, suspended by two one-inch diameter iron rods welded to the plates and supported from wooden frames in the manholes. The iron supporting rods were later found to be badly attacked and were replaced by two-inch by four-inch redwood hangers. The hangers were long enough so that the plates hung vertically in the upper zone of sludge, with the tops about two feet below the surface. Heavy copper cables protected with heavy rubber covers were connected to the plates and carried out of the manhole and across the roof to the central platform of the digester.

A Westinghouse "Rectox" rectifier (see Fig. V), connected to the lighting circuit, provided direct current. The two anode cables were connected to the output or positive terminals of the rectifier. The return or negative terminals were connected to the main bus of a test panel.

In order to provide for definite return paths for current from the various parts of the tank, individual wires were connected to these parts and brought to the test panel. Connections were made to the hot water pipes at three points outside the tank, to all sludge and other piping, to the steel beams supporting the roof, to eight points in the steel reinforcement, to the driving machinery and by sliding brush contacts to the upper part of the stirring mechanism. In all, thirty-two such connections were made, each with its individual wire to the test panel.

The test panel (see Figure IV) consisted of a sheet of "masonite," about five feet high and thirty inches wide, in the center of which a brass bus plate was fastened. Mounted on the panel were thirty-five polarized porcelain receptacles, one for each return wire, one for each anode cable and one for the main return to the rectifier. Each return receptacle was fitted with a homemade shunt, of three ampere capacity, across the terminals and on one side was connected to the main bus plate. Each return wire was connected to its respective receptacle and correctly labeled. Twenty-five ampere shunts were fitted across each anode cable receptacle, and a fifty ampere shunt was fitted across the main return receptacle.



Figures IV and V—Cathodic Protection Equipment

(Above) Test Panel, With Metering Receptacles, Shunt sand Ammeters. On Left Is the Rectifier Which Converts Alternating to Direct Current. (Below) The Compact Westinghouse "Rectox" Copper-Oxide Type Rectifier in Temporary Housing.

Two ammeters were provided, each with cords and polarized plugs attached, one ammeter reading to three amperes positive or negative, the other reading to one hundred amperes, positive.

Diagram No. 4 shows the schematic arrangement of the various parts of the protective system. For simplicity, only four of the return connections are shown. The supply circuit to the rectifier is not shown. The supply is 120 volt, 60 cycle, A.C. current, only about 60 watts of energy being used all told.

When the apparatus is in operation the circuit is as follows: Current leaving the rectifier passes through the anode shunts to the anode plates. Thence it passes into the sludge, and through it to the hot water coils, stirring mechanism, reinforcing steel and other metal parts. From these parts it goes by the individual return wires to the receptacles on the test panel, and through the

shunts to the bus plate. From the bus plate it passes through the main return shunt to the rectifier.

The purpose of the shunts is to provide for measuring of the current without interrupting the circuit. The anode shunts permit the current passing to each anode to be measured separately. The individual shunts permit measurement of the current returning from each part of the tank to be protected. The main return shunt provides for measurement of the total current returned and serves as a check on the other readings. The readings on the individual returns permit these circuits to be balanced in approximate proportion to the area to be protected, and also indicate whether the connections are in good condition.

The Westinghouse rectifier has a capacity of 30 amperes at 3.2 volts, direct current, and is so designed that several combinations of voltage and amperage may be obtained. However, experience dictates that those tappings which produce 20 amperes at 2.2 volts should be used; and, thereby, the total power used is only that required for a medium size electric light. One-half the current is sent to each anode and the return circuits are balanced to carry from 0.25 to 1.5 amperes each. Readings are made and recorded periodically to note changes.

The Anodes

The steel-plate anodes are hoisted out for inspection from time to time and are replaced as needed—(see Figure VI). When removed, the plates are found to be covered with a black honeycombed crust about two inches thick, while underneath the crust the plates are deeply pitted and eaten away at the edges. The wooden hangers are not affected, nor does the crust seem to affect the operation of the plate as an anode. One pair of plates, originally weighing 195 pounds each, were found to weigh 90 pounds each, after fourteen months of service. Each plate lost, therefore, 105 pounds or 7.5 pounds per month. This equals approximately 9 pounds of iron per ampere per year. Figure VII shows the condition of an anode, after final removal. This plate has been left in service too long. It is probable that the anodes should be replaced after nine to twelve months' service at the Terminal Island plant. At other plants the service period per anode may be longer or shorter, depending upon local conditions.

The cost of the installation was about $200.00, of which $140.00 was for the "Rectox" rectifier. This cost does not include labor, which was done by the plant operators, under the supervision of the writer. It is indicated that anode replacements will cost $10.00 to $15.00 per year, depending on conditions. The power cost is truly negligible.

Most of the anti-galvanic cathodic protection equipment was put in operation about the middle of December, 1938, using a home-made motor-generator set for power supply. The "Rectox" unit was purchased and installed later.

Results

It is unfortunate that no definite information can be given at this time as to the results of this method of protection, as no opportunity has occurred to make a complete inspection of the interior of the digester. Three things, however, seem to indicate that the protection has been effective.

First: On May 5, 1939, after about five months of operation, an inspection was made of the scum and upper mechanism in the digester, and the previously attacked parts of the scum breaker truss were found to be in excellent condition, the "Bitumastic" coating being intact. This indicated that no noticeable corrosion was taking place in this part of the merchanism.

Second: If the corrosion had continued at the alarming rate that it had during the first fourteen months, it seems highly probable that some of the structural parts of the mechanism would have failed entirely in the nearly two years of operation since the protection was installed.

It was gratifying to note that, when for test purposes, the rectifier was shut off, the current in certain of the individual return circuits immediately reversed. This was exactly what was to have been expected from the results of the experiments with the "pot" model, indicating that the conclusions drawn therefrom had been correct. It also indicated what might have been expected if anti-galvanic protection had not been applied. Further than that, it indicated that all spots could not be reached with the protective coating applied to the metal parts in place.

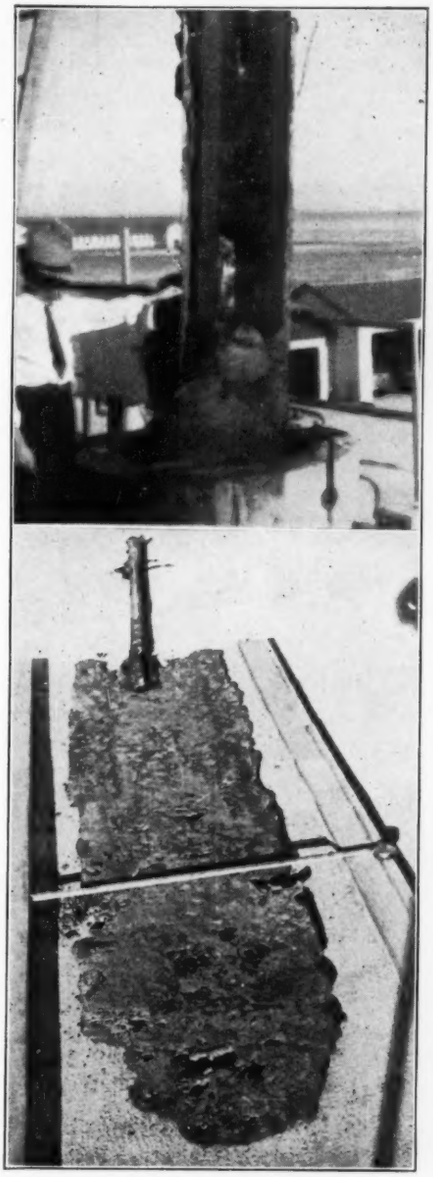
In the near future it is planned to install new sludge mixing equipment and new vertical type heating coils in the digester, to convert it into the first stage of a two-stage system, which will involve use of the decantation tanks as secondaries. When the tank is emptied for this work, a complete inspection will be made. It is our intention to make the results of this inspection and subsequent opinions, or changes in procedure, public at a later date.

In the meantime, the writer hopes that others will interest themselves in the matter of possible electrolytic corrosion, not only in digesters, but in other units of treatment plants as well.

Acknowledgments

The writer is indebted to Mr. Otto Wiemer, earlier mentioned in this paper, for his assistance in the field and laboratory and the solution of the problem was in a large measure due to his wide knowledge of the fundamentals of electrolysis and electricity in general. The plant operators, particularly Mr. Fiscus, Chief Operator, deserve praise for their help and ingenuity in solving many problems of application.

The Terminal Island Sewage Treatment Plant is part of the sewer system of the city of Los Angeles, California, and is operated under the Board of Public Works. Mr. Lloyd Aldrich is City Engineer. Mr. H. G. Smith is Engineer of Sewer Design and the writer was, at the time of these investigations, Assistant Engineer in charge of plant operations.



Figures VI and VII—The Inexpensive Sacrificial Steel Anode

(Above) Hoisted Out for Inspection. Note Crust Adhering to Plate. (Below) An Anode After 14 Months of Service; Little Being Left But Metal Lace and Wood Frame. Frame Strips Show Original Size of Anode.

EQUIPPING THE SEWAGE PLANT LABORATORY

With Particular Reference to the Smaller Plants

By NORMAN C. WITTWER, Consulting Engineer
Trenton, New Jersey

SEVERAL excellent articles have been published on the arrangement and functions of large sewage treatment plant laboratories, but very little definite information is available pertaining to a laboratory suitable for sewage plants of from 0.5 m.g.d. to 10.0 m.g.d. capacity. It is the purpose of this article to describe in detail the furnishing, equipping and arranging of a compact laboratory suitable for necessary routine control and statistical determinations.

No discussion will be made of the methods of sewage analysis, or of laboratory technique, as these subjects are thoroughly covered in such publications as the "Standard Methods of Water Analysis," published by the American Public Health Association, and "Analysis of Water and Sewage," by Theroux, Eldridge, and Mallman, published by the McGraw Hill Book Co., New York City.

The laboratory herein considered is complete in every respect for the average sewage treatment plant, although special conditions or plant processes may require some additional facilities. The analyses which may be performed in the laboratory to be described are:

Solids—Suspended, Dissolved and Volatile.
Sludge—Moisture, Solids, Ash.
Sludge Index (Activated Sludge).
pH—Sewage and Sludge.
Dissolved Oxygen (D.O.).
Bio-chemical Oxygen Demand (B.O.D.).
Oxygen Consumed.
Chlorine Demand.
Residual Chlorine.
Relative Stability (although not recommended).

*When this article was written the author was Supervising Engineer for the Rahway Valley Joint Meeting, the authority which operates the sewer systems and a central treatment works for Rahway, N. J., and eight other participating municipalities.—Ed.

Special apparatus has not been provided for sewage gas analysis, nitrogen determinations, or for bacteriological work. Such determinations are not ordinarily a part of routine laboratory work, although many of the larger plants undertake more extensive analyses.

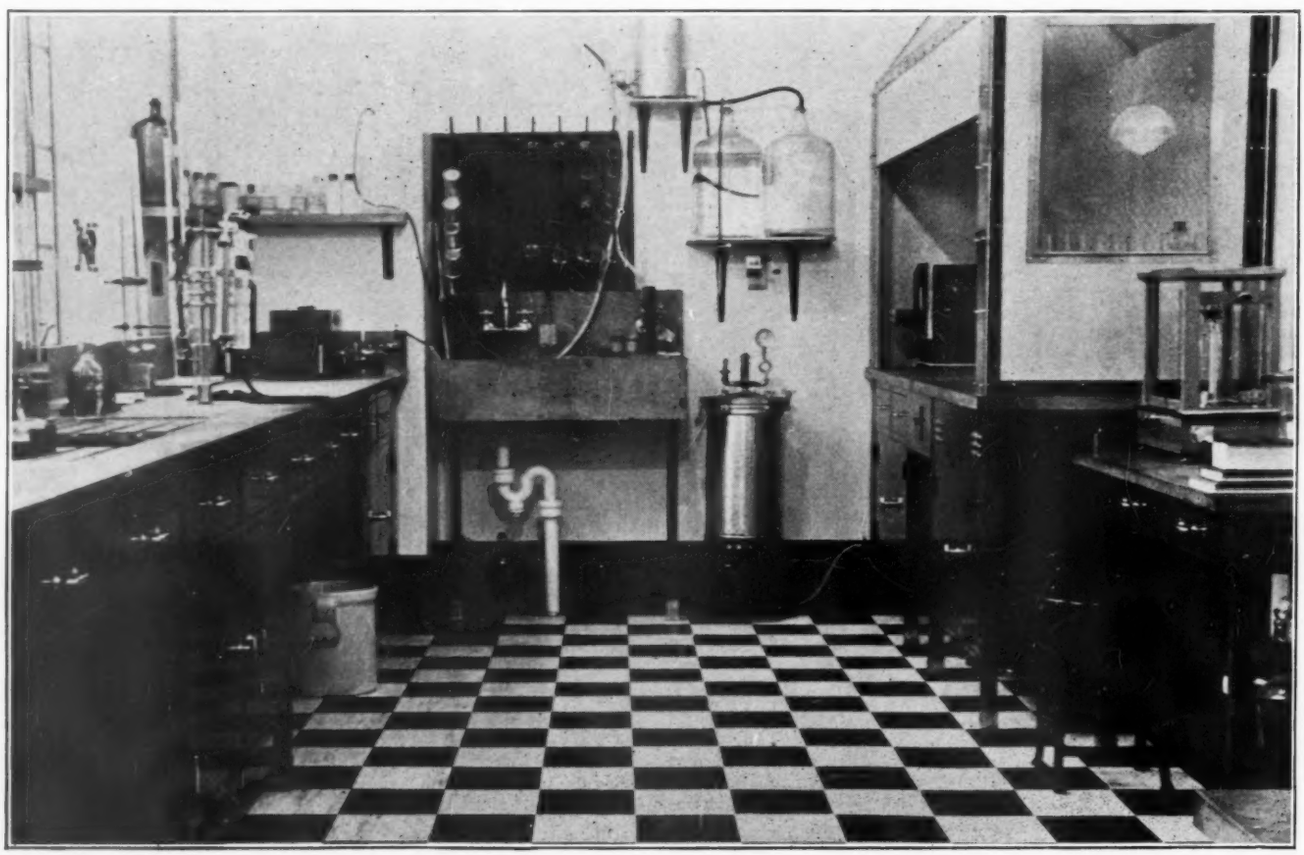
Laboratory Furniture

The scope and arrangement of the laboratory is of prime importance. Many plant laboratories have been laid out and constructed with but scanty appreciation of the facilities required. Since cost is in most cases of great importance, it is the aim of the author to present a laboratory which is compact, entirely complete for the purpose intended, and yet as economical as is possible without sacrificing needed facilities or necessary quality of equipment and apparatus.

Such a laboratory is complete in a room 12 feet wide by 15 feet long. It is based on the experience gained in the author's own laboratory, and in laying out laboratories for other plants.

Certain fundamentals are essential, and must be provided if the worker is to be expected to properly perform his duties. They are as follows:

1. Adequate work table space.
2. A suitable sink with goose-neck faucet with at least 15 inches clearance above sink bottom, and a peg board for draining and drying glassware.
3. A dependable supply of distilled water.
4. An adequate number of gas, air, hot water and cold water hose cocks, and other necessary connections.
5. Fume hood with forced ventilation.
6. Balance table.
7. Electric refrigerator for storing and preserving samples.
8. B.O.D. Incubator.
9. Drying oven.



One End of the Laboratory—Rahway Valley Plant

10. Steam bath.
11. Muffle furnace (for ashing solids).
12. Arrangement for filtration through Gooch crucibles.
13. Cabinets for reagents and solutions.
14. Shelving for small bottles, etc.
15. Cupboard and storage space for glassware, miscellaneous equipment and supplies.
16. Adequate light, a very important consideration.

Furniture Specifications

Laboratory workers differ in their preferences for wood or steel furniture, and for stone or hard-wood work-table tops. This is not so important, as both have proven satisfactory. A set of detailed specifications are given below, which are extracted from the contract specifications for a sewage treatment plant laboratory now under construction. These specifications are for steel equipment, but can be readily adapted to wood furniture if so desired.

1. *Make of Furniture*—The furniture installed under this contract shall be from a manufacturer who has made at least five satisfactory installations of steel laboratory furniture of materials such as are herein specified, and which installations have been in satisfactory service for two or more years.

2. *Steel*—Sheet steel shall be of a copper-bearing steel alloy, containing not less than one-quarter of one per cent copper, and shall be hot-lead-coated on both sides, on sheared edges and spot welds so that the steel shall be fully protected against corrosion. All sheets shall be prime grade, stretcher-levelled, free from uncoated spots, deep scratches or other injurious defects. All drawer heads and cupboard doors shall be of No. 12 gauge thickness; drawers and small shelves shall be of No. 20 gauge, all other sheet steel work shall be of No. 18 gauge. Gauges specified above and elsewhere herein are U. S. gauge.

3. *Cabinets and Supports*—All cabinet work shall be sanitary, vermin-proof flush type, without recessed or projecting panels. It shall be designed and constructed for laboratory use, with pipe ducts, racks, removable backs, shelves and adjustable legs for levelling.

Sides, backs and bottoms of cabinets shall be of No. 18 gauge. Sides of cabinets shall be of one piece, formed into a U-shaped corner post at the front, the inner sides of which shall be formed into a door strike. The upper and lower edges of the cabinet sides and back and front rail shall be formed into a channel member ,reinforced with a continuous angle frame of 1¼ x 1¼ x ⅛ inch copper steel, mitred and welded at the corner, to which the legs shall be welded. Backs and shelves shall be removable from the inside, so that piping may be installed or removed without dismantling any part of the table. Backs shall fit into clips at the bottom. At the top, the back shall be flanged in a 7/16 inch flange or back panel, and shall be held in place with two screws at the ends.

Legs of cabinets shall be of No. 14 gauge, 1½ inch square seamless tubing, 8 inches high; and shall be acetylene-welded to the angle iron frame of each individual cabinet at the bottom of the cabinet. After the legs are welded to the frame, the frames with th eattached legs shall be dipped into a vat of hot lead so that all surfaces and welds shall be fully coated and protected. Each leg shall be fitted with a drive fitting, non-ferrous die-cast, micro-levelling device, with six prongs and clip wells. The shoulder of the levelling devices shall rest on the bottom of the square tube legs, and shall then be permanently attached to the leg by forcing the metal leg into the depression on the device. The shoulder shall extend ¼ inch below the bottom of the leg. Each levelling device shall be fitted with a 2½-inch long hexagonal bolt, cadmium plated and furnished with stainless steel floor plates. The levelling device shall be covered with a duraluminum shoe cover plate as hereinbefore specified.

Cupboard doors shall be of No. 12 gauge, hung on a pair of No. 10 gauge, lead dipped, offset, five knuckle hinges, with round head brass fixed pins and with concealed flaps; one flap shall be blank and welded to the door, the other shall be fastened to the cabinet post with three bolts. Doors shall be provided with a lead-plated three-way locking device, locking both doors at the top, bottom and center at one time by a not less than 2⅜ x 1⅜ inch oval shaped, solid cast aluminum alloy knob with a ⅜ inch square brass stem cast and pinned into the knob engaging a stamped locking cam of No. 12 gauge and two ⅝ x ⅛ inch sliding bolts.

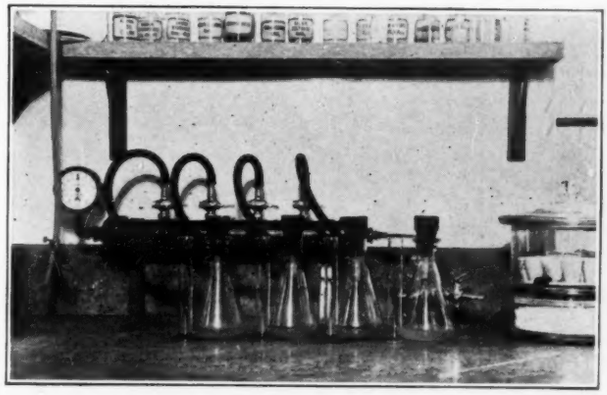
Drawers shall be of No. 20 gauge, the upper edge of the sides and back of which shall be reinforced and formed into a U-shaped head. The front of the drawers shall be of No. 12 gauge. Each drawer shall operate on four ⅞-inch diameter cadmium-plated ball-bearing rollers, operating on extension channel runners. Runners shall be formed of No 14 gauge, and shall support the drawers rigidly when extended the full length. The drawer stop shall be fastened to the bottom of the drawer, and shall be concealed at all times. Drawer pulls shall be graceful in design and shall be of cast-aluminum alloy, fastened from the inside of the drawers with concealed aluminum alloy screws. The drawer pull shall not extend into drawer.

4. *Hardware*—All hardware, including the kick-plate shoes, shall be as described under laboratory cabinet construction and shall be of cast silicon-aluminum alloy, ground and polished to a satin finish. All screws shall also be of same aluminum alloy. All cocks and table fixtures shall be chromium plated.

5. *Finish*—All surfaces of steel work of laboratory equipment shall be first washed clean with benzine to remove all the oil and grit. Then one coat of neutral metallic filler shall be applied, baked and sanded; then one coat of rust preventing primer baked and sanded; finally two coats of dark green acid and alkali resisting enamel shall be applied.

6. *Main Work Table*—The main work table along the front wall of the laboratory (see plan) shall be 15 feet long (approximately) by 2 feet 6 inches wide by 37 inches high. The table top, the 6-inch high back, and the 4-inch cut-out at the window shall be of 1¼-inch soapstone. The sink in the table shall be 18 x 16 x 8 inches deep, and furnished with a Duriron waste fitting. The table shall be supported on complete combination drawer and cupboard units, with a 5-foot clear opening in front of the window. Drawers shall be provided for the full length of the table, with a dummy drawer in front of the sink to match the rest of the equipment. A 12-inch deep open shelf shall be provided across the clear opening in front of the window, with flange-up back and flange-down front. It shall be mounted at the bottom of the cupboard and toward the rear of the opening.

7. *Vacuum Manifold*—The table shall be equipped with one vacuum manifold fitted with four 3-way exhaust cocks and one 3-inch dial vacuum gauge. The manifold shall be mounted on suitable supports at the back of the table, and connected to the vacuum pump cock by means of flexible copper tubing with compression type couplings.



Vacuum Manifold and Filter Flasks
(Used in determination of total suspended and settleable solids. On right Gooch crucibles in desiccator.)

The 3-way cocks shall be fitted in the side of the manifold facing the front of the work table.

8. *Fittings for Main Work Table*—The sink shall be fitted with one combination hot and cold water goose neck drop faucet with hose end, the goose neck to be of such height as to clear 1000 ml. graduated cylinders. A cold water faucet shall also be provided, same to have a screw-type opening suitable for a Chapman aspirator. The table shall also be equipped with one pedestal type single air pressure cock, three pedestal type double gas cocks, and one pedestal type cold water cock.

9. *Vacuum Pump*—There shall be installed on the shelf of the cabinet space under the sink a suitable blower and vacuum pump for the operation of the vacuum manifold. These conditions are satisfied by a Cenco Rotary air cooled blower and vacuum pump driven by a ¼ horsepower motor mounted on a common base. (The electrical current characteristics must be given for the motor.) The motor shall be controlled by a push-button switch located at a convenient point on the wall above the main work table.

The vacuum side of the pump shall be connected with ¼-inch copper tubing, or extra heavy vacuum rubber tubing, to the exhaust manifold as indicated on the drawings. The pressure or exhaust side of the pump shall be connected to the air cock on the main work table with ¼-inch copper tubing.

10. *Work Table Shelving*—There shall be furnished and in-

stalled on the wall above the main work table, 1¼-inch thick by 6 inches wide soapstone reagent shelving mounted 22 inches above the top of the work table. The shelves shall extend along all walls of the work table, except for the window and peg board. The shelves shall be supported on suitable brackets, securely fastened and anchored to the building wall.

11. *Peg Board*—There shall be mounted on the wall at the right end of the work table a peg board of carbonized wood, 24 inches wide by 30 inches high.

12. *Fume Hood*—The fume hood shall be an open type fume hood 5 feet long by 2 feet 6 inches wide. The work table of the hood shall be supported by one 2½-foot combination drawer and cupboard unit. The hood shall be furnished with one 1000-watt pedestal-type duplex electric receptacle, two pedestal-type double gas cocks, one pedestal-type double water cock, and one four-hole gas-heated steam bath.

The steam bath shall be fully insulated, with a gas vent opening on the inside of the fume hood. The steam bath shall be constructed of No. 18 gauge stainless steel, and equipped with stainless steel concentric rings to cover the four 3¾-inch diameter openings. The bath shall be of the quick-steaming type, equipped with a suitable external water level regulator. A Hoke-Phoenix needle valve shall be used to control the water supply to bath, and the bath overflow shall be visible.

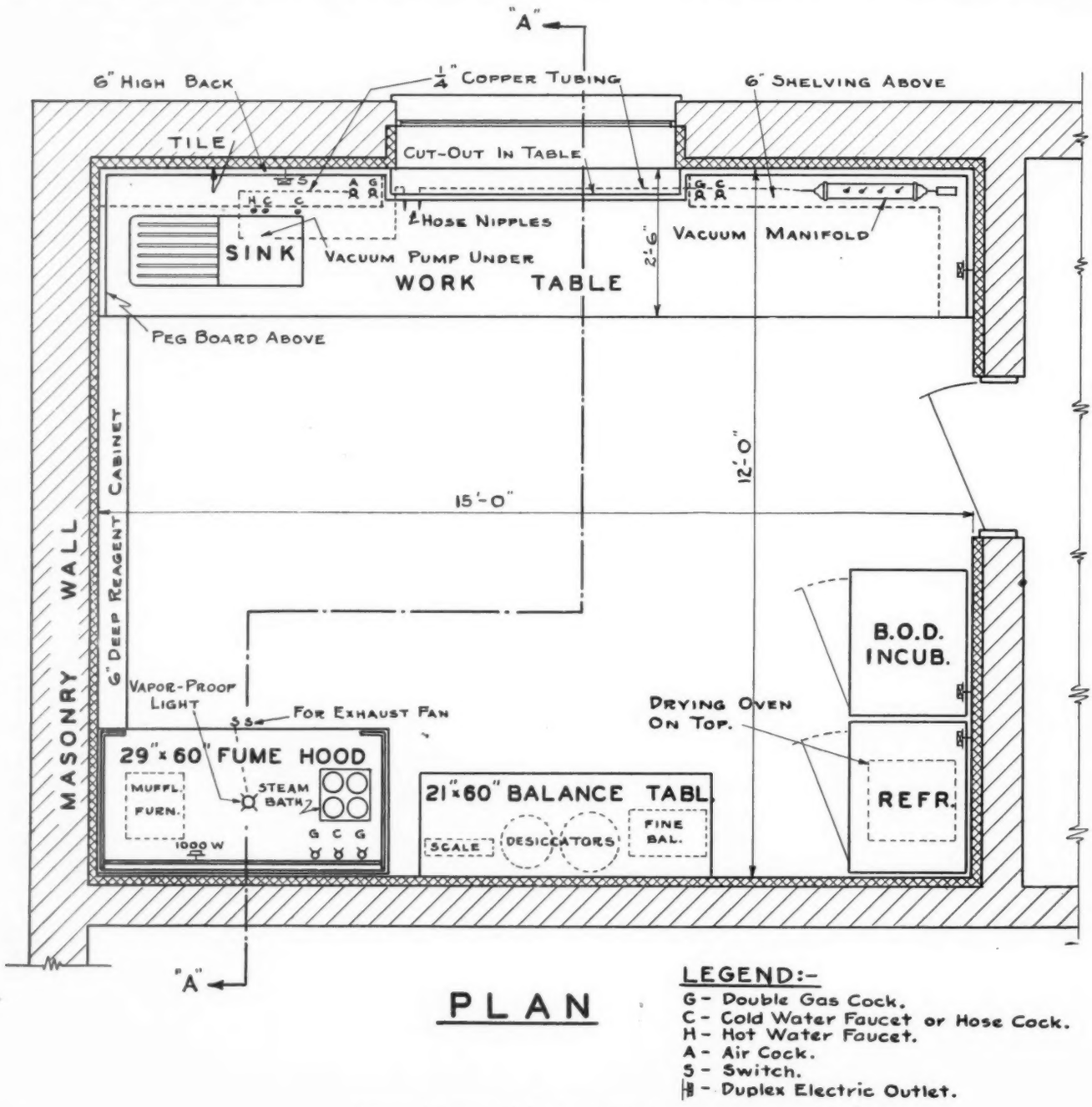
A suitable opening and connection shall be provided through to the top or rear of the hood for the installation of the exhaust fan.

13. *Hood Exhaust Fan*—A suitable exhaust fan shall be installed to exhaust the fume hood. The fan shall have a capacity to discharge not less than 225 cubic feet of free air per minute at free delivery.

The fan suction and discharge piping shall be of suitable acid fume resisting material, such as "Labite," "Transite," or vitrified tile. All joints shall be air tight, and the joints at the fan shall be made with high-grade, heavy rubber tubing to prevent vibration.

The exhaust piping shall terminate at the roof in a suitable size ceramic ventilating roof cap, properly flashed to the roof.

14. *Other Shelving*—There shall be furnished and installed the necessary shelving for the water still and the two 5-gallon distilled water carboys. If possible, the water still can be mounted on top of the reagent cabinet. The shelf for the 5-gallon car-



PLAN

LEGEND:-
G - Double Gas Cock.
C - Cold Water Faucet or Hose Cock.
H - Hot Water Faucet.
A - Air Cock.
S - Switch.
Duplex Electric Outlet.

Suggested Layout of Sewage Works Laboratory

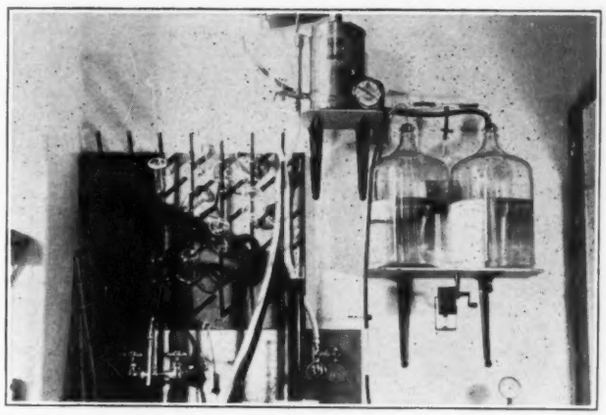
boys shall be of ⅜-inch Labite or Transite, 22 inches wide by 11 inches deep. It shall be mounted on heavy brackets of sufficient strength to carry the weight of the bottles, when full.

All brackets shall be securely fastened and anchored to the building wall.

15. *Balance Table*—The balance table shall be 5 feet long by 1 foot 9 inches wide by 2 feet 7 inches high, and shall be constructed of 1⅝-inch diameter tubular steel with a cross bar at rear only to provide ample leg room. The floor flanges shall be such as to permit levelling of the table. A 4-inch high panel shall be provided under the table top into which shall be fitted two small drawers. The table top shall be of 1¼-inch selected soapstone.

16. *Reagent Cabinet*—There shall be furnished and erected an enameled steel reagent cabinet, 7 feet high and of suitable length, and 6 inches clear depth. The cabinet shall be constructed of No. 18 gauge steel with sliding steel doors glazed with No. 1 clear glass. The cabinet shall have five shelves, adjustable in height. The cabinet shall have three front legs, with provisions for bolting the cabinet securely to the wall.

The approximate cost of the laboratory furniture specified above is $1,250.00.

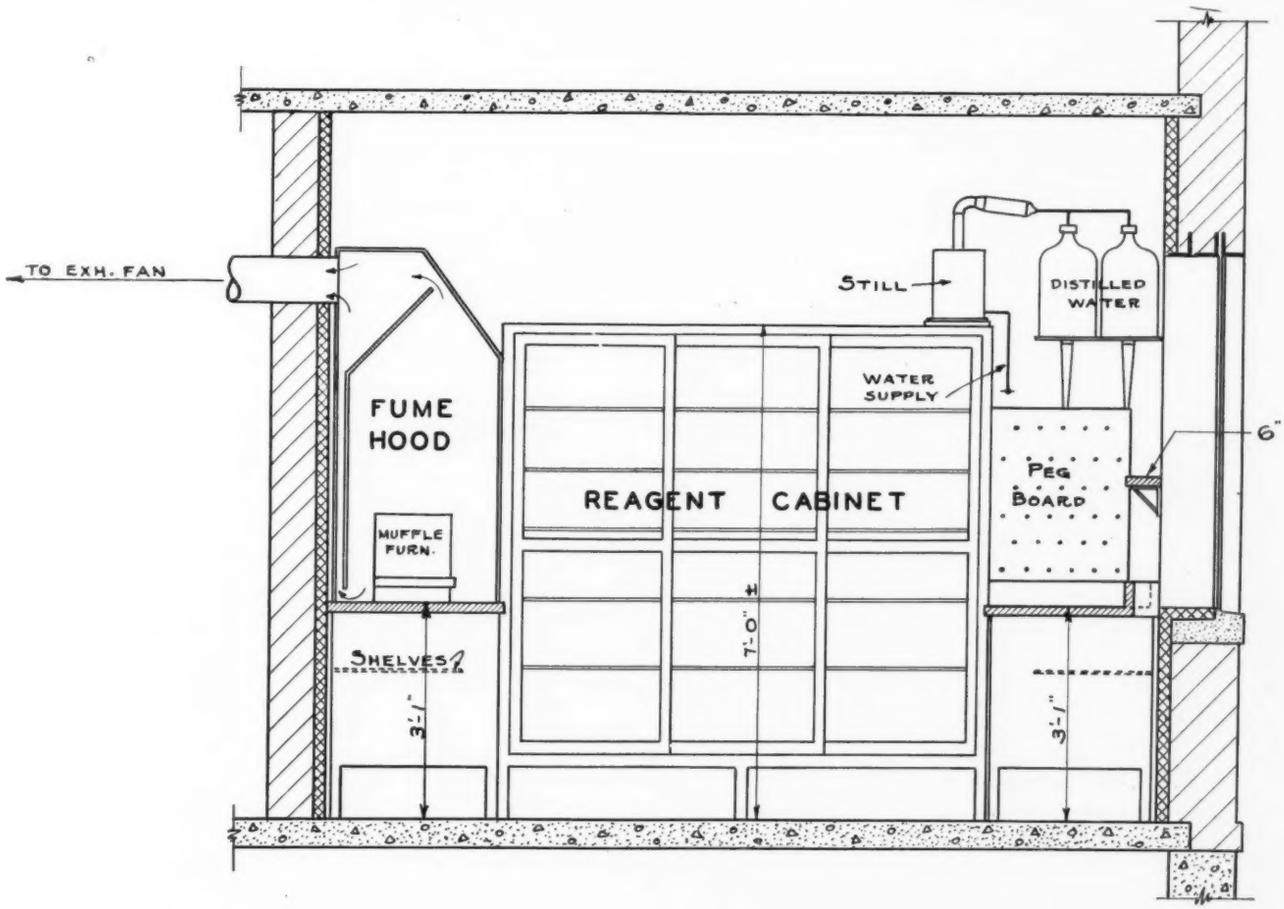


Peg-board Above Sink and Water Still on Right

Permanent Apparatus and Equipment

In addition to the laboratory furniture, certain permanent apparatus will be required. The following list of this apparatus, as well as the "Minor Equipment Items" list and the "Reagents and Chemicals" list, has been carefully compiled, and checked against the equipment and experience of active plant laboratories. The "loading up" of the laboratory with unnecessary or little-used apparatus and equipment has been avoided. Enough equipment has been included to enable the chemist or operator to walk into the laboratory and commence work, without the all-too-customary wait for necessary items not originally included.

In the preparation of such lists, cognizance is taken of the fact that certain manufactured items of equipment and apparatus have been found to be the most satisfactory for use in a sewage plant laboratory. It is also recognized that a general description of a particular item without the corresponding manufacturer's name or catalog number will not always enable a purchaser to obtain the article intended. Therefore, wherever deemed advisable, the manufacturer's name or dealer's catalogue number is



SECTION "A-A"

Suggested Layout of Laboratory—Section "A-A"

included in order to eliminate errors in the purchase of this equipment. Wherever possible, more than one manufacturer or dealer will be given.

The following abbreviations will be used throughout for several of the more prominent supply houses:

Arthur H. Thomas Company.....AHT
Eimer & Amend.....E&A
Central Scientific Co.....CSC

The catalog numbers thus given can be considered as standards of quality by which other competing houses can offer their merchandise.

Quantity	Description
1	B.O.D. Incubator 5 to 6 cu. ft. capacity (give current characteristics).
1	Analytical Balance with chain balance with channel notched beam, sensitivity to 1/20 mg. with magnetic damper, Christian Becker chainomatic No. 16, or E&A 16772/2.
1 set	Analytical Balance weight, 1 gm. to 100 gm. for chain balance.
1	Rubberized Balance Cover to fit balance.
1	Triple Beam Balance with agate bearings, including sliding weights and 500 gm. and 1000 gm. attachments. Equal to E&A 17026, 17026 A&B, or CSC 3600 & 3610.
1	Beckman pH Meter (Industrial Model).
1	Taylor-Enslow Slide Chlorimeter (where chlorine is being used).
1	Muffle Furnace, MU Type 62 Electric and Encased Rheostat (give current characteristics).
1	Electric Drying Oven, inside dimensions approximately 12" x 12" x 15", with inside glass door. Elconap Type BO 15, or Weber Type B (give current characteristics).
1	½ gallon per hour Automatic Water Still, as made by either Barnstead or Stokes. May be for electricity or sewage gas. If for electricity give current characteristics.
1	International Clinical Electric Centrifuge with a 4-place combination head for two 15 ml. tubes and two 50 ml. tubes (give current characteristics).
4	15 ml. graduated resistance-glass conical-bottom centrifuge tubes.
4	50 ml. graduated resistance-glass centrifuge tubes with spouts, E&A 20065/4.
1	5 cu. ft. standard make electric refrigerator.

The approximate cost of the permanent apparatus listed above is $1,110.00.

It is possible to substitute cheaper equipment for some of the items specified, but such substitutions will inevitably result in frequent breakdowns and repairs, and unsatisfactory results. After all, the old axiom that "a workman is as good as his tools" holds good in a sewage plant laboratory as well as in a shop.

The centrifuge listed above is not absolutely necessary, but has been found to be very useful for controlling the drawing-off of supernatant liquor from digestion tanks, and in the operation of activated sludge plants.

Some chemists and plant operators still use colorimetric apparatus for pH determinations. However, a potentiometer, such as the Beckman pH Meter, specified above, is not only more accurate, particularly with sludges, but is also a great time saver to the busy worker.

Minor Equipment Items

This list includes all minor and renewable items such as glassware, brushes, burners, rubber tubing and stoppers, etc. Sufficient glassware is included to allow for reasonable washing intervals.

Quantity	Description
1	Actigel Analytical Balance Desiccator.
1	Fruhling & Shultz Desiccator, 10-inch, with cover and 10-inch Coors porcelain perforated plate.
1	Fruhling & Shultz Desiccator, 8-inch, with cover and 8-inch Coors porcelain perforated plate.
2	Balanced Watch Glasses, 3-inch (1 pair).
	Beakers, No. 1000 Pyrex Griffin low form with lip.
2	1000 ml. capacity
2	600 ml. capacity
4	400 ml. capacity
12	250 ml. capacity
6	100 ml. capacity
4	50 ml. capacity
	Bottles, Narrow Mouth, Flint Glass, round, for corks, AHT 2203, E&A 18652.
12	12 oz. capacity
12	8 oz. capacity
18	300 ml. B.O.D. Bottles, glass-stoppered with stoppers numbered consecutively from 1 to 18 to correspond with numbers on bottles. Numbering to be in black enamel figures. Bottles to be of Non-Sol-Vit glass, and not over 6½" in height, including stoppers. (18 bottles will permit two determinations weekly on raw sewage and effluent.)
	Bottles, Narrow Mouth, glass stoppered tincture, with well ground flat stoppers, AHT 2220 or E&A 18680.
12	1000 ml. capacity
24	500 ml. capacity
12	250 ml. capacity
4	30 ml. Round Dropping Bottles with flat, grooved stoppers, AHT 2257 or E&A 18824.
4	30 ml. Square Dropping Bottles with rubber bulb stoppers and glass pipette E&A 18806.
1	Washing Bottle, 1 liter Pyrex complete with rubber stopper, glass tubes and rubber tubing joints.
4	5-gallon Narrow Mouth Glass Bottles, E&A 18650 (for distilled water).
6	2-gallon Narrow Mouth Glass Stoppered Bottles, AHT 2210-A (for B.O.D. dilution water and standard solutions).
4	1-gallon cider jugs (for compositing and storing samples).
1	Superior quality camel hair brush with wooden handle and ½-in. dia. tuft., AHT 2376 or E&A 19048 (for dusting scale pans).
6	Medium camel hair brushes, AHT 2378 or E&A 19042 (for cleaning watch glasses).
12	Test Tube Brushes with Puff Tuft end, tinned iron wire handle, 1½-inch diameter bristles, AHT 2389.
1	Cylinder Brush, bristle end, strong rattan handle, bristle 2 inches diameter by 4½ inches long, total length 25 inches, E&A 19072.
6	Pipette Brushes, length of bristle 7½ inches, AHT 2382, E&A 19074.
2	Burette Brushes, brass wire handles, tufted bristle end, AHT 2396.
4	Brushes, of black bristle, total length 12 inches, AHT 2363 or E&A 19092.
3	50 ml. Schellbach Burette with large straight glass stopcock, AHT 2436.
1	50 ml. Schellbach Burette with large three-way glass stopcock, AHT 2438.
2	Fisher Burette Supports, complete with clamps, base 7" x 13" Opal White Glass, nickel-plated support rod, E&A 31915.
4	Fisher High Temperature Burners, AHT 2596 or E&A 19309.
4	Apparatus Supports for Fisher Burners, AHT 2599.
6	Clamps, cataloy, cadmium plated with 1½-inch effective jaw opening, E&A 20195.
3	Heffman Pinchcocks, ¾" x 1⅛", AHT 3270, CSC 12195, or E&A 20294.
6	Mohr Pinchcocks, ⅝-inch opening, AHT 3278 or E&A 20298.
2	Test tube Clamps AHT 3246.
	Non-absorbent Cotton (1 pound).
	Corks, first quality, assorted in sizes No. 1 to No. 14, E&A 2119 (1 gross).
	Cork Borers (1 set 3/16 inch to 13/32 inch), AHT 4068, E&A 21213, or CSC 12465.
6	Vitreosil Opaque Fused Silica Dishes, 100 ml. E&A 22000.
3	Vitreosil High Form Opaque Fused Silica Crucibles, without covers, E&A 21248.
24	No. 270 Coors Porcelain Gooch Crucibles, Size No. 3 (25 ml. capacity) without covers.
4	Crucible Holders, Walter, E&A 23050, to fit the filter flasks, Item No. 38.
4	500 ml. No. 5340 Pyrex Filter Flasks.
1	Crucible Tongs, nickel-plated brass, 12 inches long, E&A 32553.
1	Crucible Tongs, nickel-plated brass, 16 inches long, AHT 9701.
1	Crucible Tongs, cast brass, 8 inches long, AHT 9692.
	Cylinders, single graduated Pyrex, AHT 4409, E&A 21652, CSC 16140.
2	1000 ml. capacity
1	500 ml. capacity
6	100 ml. capacity
2	50 ml. capacity
	Whatman No. 2 Filter Paper—15 cm. diameter (6 boxes).
	Grey Filter Paper, 33 cm. diameter, E&A 23156 (* pkgs.).
12	5-inch Triangular Files, AHT 5083.
12	Pyrex Erlenmeyer Flasks, 250 ml. No. 4980.
	Volumetric Flasks, resistance glass with ground glass stop-

pers (two graduations to contain and deliver), AHT 5465.
1 1000 ml. capacity
1 500 ml. capacity
1 250 ml. capacity
1 100 ml. capacity
Funnels, Glass, ground rim and thin stem about 10 cm. long ground to a point, AHT 5570, E&A 23622.
4 6.5 cm. diameter
2 10 cm. diameter.
1 Ribbed-Glass Funnel, 18 cm. O.D. of rim, E&A 23632, AHT 5584.
2 No. 430 Coors Porcelain Evaporating Dishes, Size No. 2, 120 ml. capacity.
12 Glass Stirring Rods, 3/16", E&A 24562.
Glass Tubing, soft glass, regular wall, E&A 24570.
5 mm. O.D. (2 lbs.)
7 mm. O.D. (2 lbs.)
8 mm. O.D. (2 lbs.)
1 No. 520 Coors Porcelain Mortar & Pestle, Size No. 2 (115 mm. inside diameter).
1 No. 550 Coors Porcelain Spot Plate, Size No. 00 (92 x 112 mm.).
1 No. 624 Coors Porcelain Pipette Rest.
No. 650 Coors Porcelain Spatulas.
1 Size 2, 142 mm. long
1 Size 4, 195 mm. long
1 Bottle Cenco Ceramic Marking Ink, CSC 14000.
No. 37000 Exax Blue Line Transfer Pipettes.
2 10 ml. capacity
3 25 ml. capacity
2 50 ml. capacity
No. 37020 Exax Blue Line Mohr-type Measuring Pipettes.
2 1 ml. capacity
2 2 ml. capacity
2 5 ml. capacity
6 10 ml. capacity
1 Pipette Support, revolving, of hardwood, with 3 decks revolving on wooden base, AHT 8264.
Rubber Tubing, Best Heavy White Wall, ½" x ⅛", for automatic still connections, E&A 30683 (12 ft.).
Rubber Tubing, Heavy Red Wall, ⅜" x ⅛", E&A 30703 (12 ft.).
Rubber Tubing, Heavy Red Wall, ¼" x 3/32", E&A 30703 (12 ft.).
Rubber Tubing, ¼" Extra Heavy Vacuum for vacuum pump and aspirator connections, E&A 30710 (12 ft.).
6 Rubber Policemen, 3/16 inch, E&A 30734.
Rubber Stoppers, Solid, No. 3, No. 4, No. 5, No. 6, No. 7, No. 8, No. 9, No. 10, E&A 30639 (1 lb. of each).
Rubber Stoppers, One-Hole, No. 3, No. 4, No. 5, and No. 6, E&A 30641 (½ lb. of each).
Rubber Stoppers, Two-Hole, No. 3, No. 4, No. 5 and No. 6, E&A 30643 (½ lb. of each).
1 Scissors (7-inch), of good quality.
1 Chapman Filter Pump, 5⅜ inches long, AHT 5286, E&A 30134.
1 Test Tube Support, double deck with 24 holes, 22 mm. diameter, with row of pins in rear, AHT 9509 or E&A 31991/1.
2 Spatulas—4-inch stainless steel blades with rosewood handles, E&A 31048.
Thermometers, AHT specifications, AHT 9525.
1 Graduated— 5° C. to 200° C. (for drying oven).
1 Graduated—10° C. to 110° C. (for B.O.D. Incubator).
1 Wood Frame Thermometer, 0-120° F., E&A 32498 (for sewage temperatures).
1 10-inch Maximum and Minimum Thermometer, self-registering, best make—40° F. to 120° F., with magnet, E&A 32416 (for recording outside air temperatures).
24 No. 9800 Pyrex Test Tubes, 150 mm. x 16 mm.
6 Triangles, 2-inch sides, E&A 32648.
Watch Glasses, E&A 32850.
12 3-inch diameter
12 4-inch diameter
12 5-inch diameter
12 5" x 5" Tinned Wire Gauzes with flat asbestos centers, E&A 33090 or AHT 9995.
12 Pencils, all-red wax.
1 4-gallon Stoneware Jar, E&A 25634, AHT 6292 (for waste materials).
1 Gas Diffuser Stones, Aloxite Brand, 1-inch diameter, E&A 24167 (for aerating B.O.D. dilution water).
Gummed Labels, Dennison No. 201, No. 209, No. 217, and No. 223 (2 boxes of each).
1 Hydrometer Cylinder, 2" dia. x 15" high, E&A 21630 (for washing pipettes in cleaning solution).
Iron Rings, combined with fasteners for attaching to iron supports, E&A 30620.
2 1¼-inch I.D.
2 2-inch I.D.
2 3-inch I.D.
2 4-inch I.D.
4 Iron Supports, Medium, 20-inch rod, E&A 31879.
Coarse Glass Wool (E&A 24638), for bottom of hydrometer to prevent breakage of pipettes (4 oz.).

The approximate cost of the minor equipment items listed above is $290.00.

Reagents and Chemicals

All reagents to be chemically pure unless otherwise noted.

Quantity	
5 lbs.	Glacial Acetic Acid, c.p.
6 lbs.	Hydrochloric Acid, Spr. gr. 1.20, c.p.
7 lbs.	Nitric Acid, sp. gr. 1.42, c.p.
1 oz.	Oxalic Acid, c.p. crystal.
18 lbs.	Sulphuric Acid, tech.
9 lbs.	Sulphuric Acid, sp. gr. 1.84, c.p.
1 lb.	Aluminum Sulphate, crystal, c.p.
8 lbs.	Ammonium Hydroxide, sp. gr. 0.90, c.p.
1 lb.	Ammonium Carbonate, c.p.
1 lb.	Asbestos, short fibres, acid washed. Powminco.
5 lbs.	Calcium Chloride, calcined, porous, gran. for desiccators, tech.
1 lb.	Chloroform, pure (Squibb).
1 lb.	Copper Sulphate, crystal, c.p.
1 lb.	Ether, Ethyl, U.S.P.
¼ lb.	Iodine, resublimed, c.p.
1 lb.	Lead Acetate, normal, c.p.
5 lbs.	Manganous Sulphate, c.p.
1 oz.	Methyl Orange Indicator.
1 oz.	Orthotolidine powder, c.p.
1 oz.	Phenolphthalein, c.p.
1 oz.	Potassium Biniodate, c.p.
1 lb.	Potassium Chromate crystals, c.p.
5 lbs.	Potassium Dichromate, tech.
1 lb.	Potassium Dichromate, c.p.
1 lb.	Potassium Hydroxide, pellets, c.p.
2 lbs.	Potassium Iodide, crystal, c.p., Bakers Analyzed Special.
1 lb.	Potassium Oxalate Neutral, c.p.
1 lb.	Potassium Permanganate, crystal, c.p.
1 oz.	Silver Nitrate, c.p.
1 lb.	Soda Lime, 4 to 8 mesh.
5 lbs.	Sodium Bicarbonate, crystal, c.p.
1 lb.	Sodium Carbonate, c.p.
5 lbs.	Sodium Chloride, crystal, c.p.
10 lbs.	Sodium Hydroxide, pellets, c.p.
1 lb.	Sodium Acid Sulphite, $NaHSO_3$, c.p.
4 oz.	Soluble Starch, Indicator Grade.
1 doz.	Litmus Paper, 6 red and 6 blue.
1 oz.	Stopcock Grease.
1 lb.	Sodium Oxalate, c.p.
5 lbs.	Sodium Thiosulphate.
¼ lb.	Thymol (to be used as a preservative for Sodium Thiosulphate Solutions).

One quart of pure Ethyl Alcohol should be purchased locally, as the chemical supply houses are not licensed to supply grain alcohol.

The approximate cost of the reagents and chemicals listed above is $60.00.

Summary of Costs

The approximate cost of furnishing and equipping the complete sewage treatment plant laboratory described above is as follows:

1.	Laboratory Furniture	$1,250.00
2.	Permanent Apparatus	1,110.00
3.	Minor Equipment Items	290.00
4.	Reagents and Chemicals	60.00
	Total Cost	$2,710.00

Acknowledgment is given to Mr. Joseph Boreiszo, plant chemist at the Rahway Valley Sewage Treatment Plant, for many helpful suggestions in the preparation of this article.

ESTIMATION OF TOTAL SOLIDS IN SLUDGES BY CENTRIFUGING

By

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Chief Chemist

and

WILLIAM L. TORREY
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AT the spring meeting of the New York State Sewage Works Association, held in Syracuse in June, 1940, the question was raised as to whether there was a satisfactory method of centrifuging sludge samples and estimating the dry solids content therefrom without evaporation, weighing, etc. In the account of this meeting, WATER WORKS AND SEWERAGE[1] reported that the Bird Island Laboratory here in Buffalo used the formula: $\frac{\%\text{ volume of centrifugal solids}}{4} = \%$ solids by weight. However, it was warned that this factor of 4 was not exact and might prove to be something different for sludges of other plants.

Interest in this question has led us to summarize the data on the volume of centrifuge solids and its relation to total dry solids. This attempt to develop a relationship consisted of plotting the data collected over a period of 12 months on daily analysis of raw and digested sludge.

Reference to the literature indicated that Smith[2] at the Calumet Sewage Treatment Works at Chicago had tried this method of centrifuging for the determination of total solids in activated sludge. It was reported that the use of 100 ml. and 50 ml. tubes was not practical because the graduations were not close enough. Smith developed a 30 ml. centrifuge tube graduated to 0.1 ml. divisions for the first 10 ml. Samples were centrifuged in a closed motor driven centrifuge for three minutes after uniform speed had been raised to 2,000 R.P.M., followed by a gradual stop. It was observed that an increase or decrease of approximately 130 R.P.M. from 2,000 R.P.M. caused a difference in reading of from 0.1 to 0.2 ml. in the volume of the sludge and that the "main cause of variation is the non-uniformity in the character of the sludge particles." As evidence of this, the variation in mineral matter after heavy rainfalls was cited. It was concluded that the "centrifuge test is probably satisfactory enough for rough plant control work, but as a matter of record, should be supplemented by actual gravimetric solids determination."

Technique of the Centrifugal Method

The technique of the test as carried out in the Bird Island Laboratory consists of the following steps:

Measure 50 ml. of sludge sample into a standard conical bottom 50 ml. centrifuge tube. Place the tube and a balancing tube in the centrifuge, and set the rheostat to control the maximum speed to 2,000 R.P.M. The time control is set and the current switched on. After 15 minutes the current is switched off and the centrifuge allowed to coast to a stop. The volume in ml. of sludge solids in the centrifuge tube is read and multiplied by a factor of 2 to give per cent by volume of centrifuge solids. It is probably safe to say that the reading accuracy is ± 0.3 ml. when the heterogenous character of the sludge is considered, for the surface of the compressed solids is usually quite uneven.

In the study of our own data, it appeared that any plot of the data would give a general scatter diagram with an upward trend. Observations had confirmed Smith's findings of the effect of character of sludge particles on the volume of the centrifuge solids. Therefore the decision was made to plot the data according to ranges of volatile matter in order to take into account this factor which involves density of the particles.

What a Study of Analytical Data Revealed

Table I for raw sludge shows the relationship of per cent centrifuge solids by volume to per cent total solids by weight, for such sludge in several ranges of volatile matter content. Table II shows similar data derived from analyses of digested sludges. The ratio of per cent centrifuge solids by volume to per cent total solids by weight is plotted in Fig. 1 against per cent volatile matter for both raw and digested sludge.

From a study of these curves, it is apparent that with an increase in volatile matter the sludge becomes more bulky and a given weight occupies a greater volume. This is true for both raw and digested sludge; and, since it is reasonable to expect that the density of sludge particles will vary inversely as the organic content, such is to be expected.

What Plotted Data Reveals

These curves indicate that for the same volatile matter content *digested sludge is more bulky than raw sludge*. At first thought this appears to be contrary to expectations. The explanation, no doubt, lies in the fact that when the volatile matter content of raw sludge decreases toward that of digested sludge, the ash increase is due to fine sand. This condition occurs during storms. Naturally, the density of the sand and silt is quite high and the raw sludge is less bulky than digested sludge of the same organic-inorganic composition, but different types of components.

Although the slope on these curves is slightly variable, it is probably safe to assume that if more observations were available, the curves would tend to become straight lines. This deviation from a constant slope appears to be more pronounced in the case of raw sludge. Such a condition is probably due to the fact that raw sludge is more heterogenous and samples are more apt to contain disproportionate amounts of large particles of non-uniform density.

Developing a Factor

Quite obviously, then, the use of a definite factor to convert centrifuge solids to total solids by weight is not permissible. If the assumption is made that these lines have a constant slope represented by a straight line drawn through the points, then formulae may be developed to show the relationship as follows:

TABLE I—RAW SLUDGES

Ratio of Per Cent Centrifuge Solids by Volume to Per Cent Total Solids by Weight at Various Contents of Volatile Solids

No. of Observations	Vol. Mat. Range Per Cent	% Vol. Mat. Avg.	% Vol. Mat. Median	% Vol. Mat. Max.	Ratio = % Cent. Sol. by Vol. / % Total Sol. by Wt. Min.	Ratio Avg.	Ratio Median
22	40.50	45.0	47.0	4.164	2.224	3.022	2.950
39	50-55	52.8	52.9	4.516	2.764	3.400	3.410
43	55-60	57.7	57.5	4.954	2.898	3.808	3.808
45	60-65	62.4	62.5	6.666	2.080	4.120	4.408
62	65-70	67.4	67.3	6.250	2.250	4.200	4.326
98	70-75	72.5	72.4	7.006	2.722	4.740	4.802
59	Over 75	78.4	77.3	7.660	2.858	5.156	5.284
368	40-91.6	65.9	67.7	7.76	2.224	4.120	

Average of 368 Observations —

Per cent Cent. Solids	23.90
Per cent Total Solids	5.80
Per cent Volatile Matter	65.9
Ratio	4.12

TABLE II—DIGESTED SLUDGES

Ratio of Per Cent Centrifugal Solids by Volume to Per Cent Total Solids by Weight at Various Contents of Volatile Solids

$$\text{Ratio} = \frac{\%\ \text{Cent. Sol. by Vol.}}{\%\ \text{Total Sol. by Wt.}}$$

No. of Observations	Vol. Mat. Range Per Cent	% Vol. Mat. Avg.	% Vol. Mat. Median	% Vol. Mat. Max.	Ratio Min.	Ratio Avg.	Ratio Median
62	35-39	37.2	37.0	4.444	2.136	2.904	2.884
54	39-43	41.3	41.5	4.232	2.636	3.294	3.210
49	43-45	44.1	44.2	4.436	2.744	3.580	3.616
53	45-47	45.8	45.7	5.064	2.462	3.738	3.836
47	47-49	48.0	48.2	5.000	2.500	3.930	3.938
49	49-53	50.7	50.7	5.156	2.602	4.118	4.058
316	35-53	43.9	43.4	5.156	2.136	3.424	

Average of 316 Observations—

Per cent Cent. Solids	33.52
Per cent Total Solids	9.79
Per cent Volatile Matter	43.88
Ratio	3.424

(A) For *Raw Sludge:*

The ratio at any given volatile matter content is:

$$\text{Ratio} = 2.7 + (\%\ \text{vol. mat.} - 40) \times 0.06$$

or

$$\%\ \text{T. S. (by wt.)} = \frac{\%\ \text{cent. sol. by vol.}}{2.7 + (\%\ \text{vol. mat.} - 40) \times 0.06}$$

(B) For *Digested Sludge:*

The ratio at any given volatile matter content is:

$$\text{Ratio} = 2.7 + (\%\ \text{vol. mat.} - 35) \times 0.09$$

or

$$\%\ \text{T. S. (by wt.)} = \frac{\%\ \text{cent. sol. by vol.}}{2.7 + (\%\ \text{vol. mat.} - 35) \times 0.09}$$

Condensed these formulae become

(A) For *Raw Sludge:*

$$\%\ \text{T. S.} = \frac{\%\ \text{C. S.}}{0.06\ (V + 5)}$$

(B) For *Digested Sludge:*

$$\%\ \text{T. S.} = \frac{\%\ \text{C. S.}}{0.09\ (V + 5)}$$

In which (V) = % Volatile Matter.

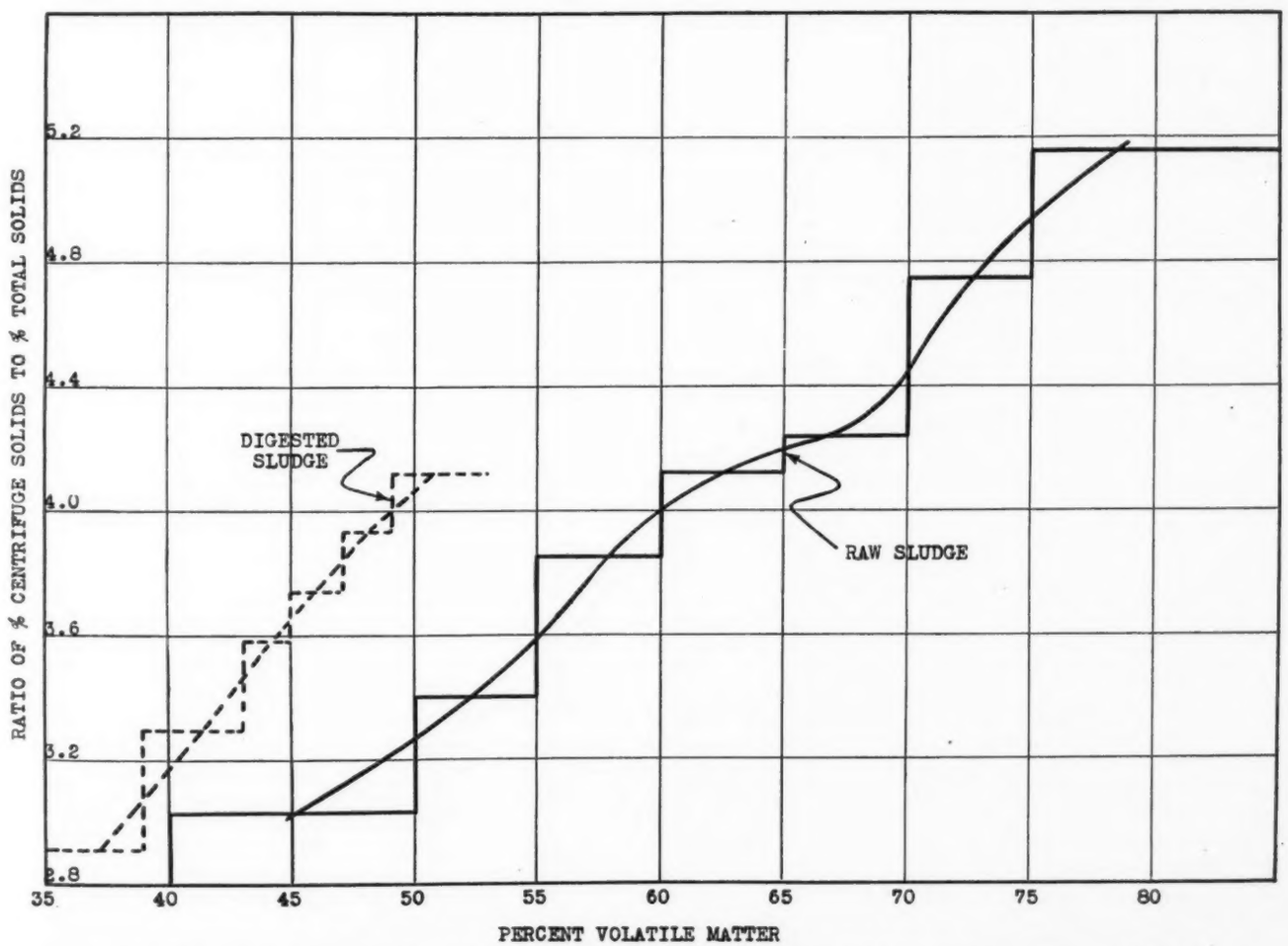


Fig. 1—Changing Ratio of Centrifugal Solids to Total Solids, as influenced by Per Cent Volatile Matter in Sludges

The accuracy of these factors determined from the slopes of the curves is well within the accuracy of the reading. This is apparent when one notes the spread of maxima and minima and when one considers the reading error for the final result may itself have an absolute error of 2 to 6 per cent in sludges ranging from 4 to 12 per cent total dry solids.

Value of the Test

Inasmuch as it appears that the volatile matter of the sludge involved must be known, the question may well be asked, "Why run the test if total solids and volatile matter must also be determined?" The answer is that the test is only applicable when an operator has an idea of the approximate composition of the sludge and desires a quick estimate of the concentrations of solids in a sludge. For example, a very quick inventory of sludge tanks can be made by the use of this test.

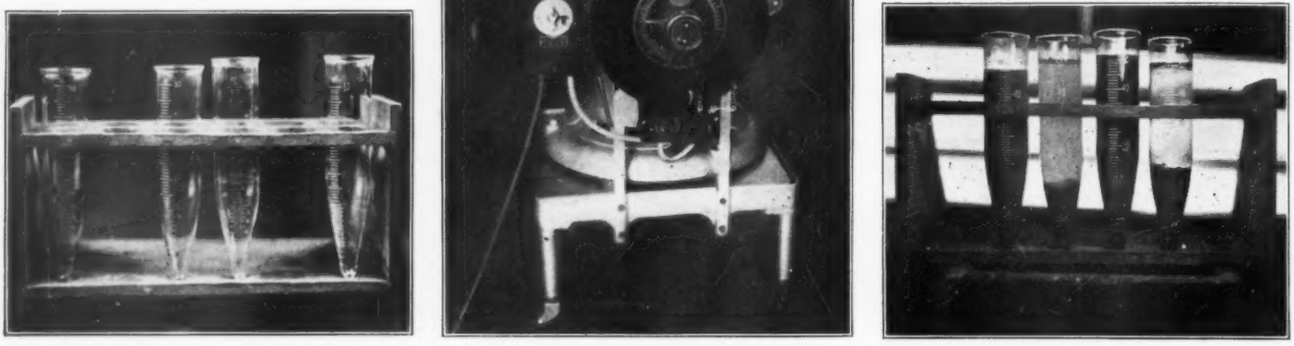
The value of this study has been to demonstrate that:

1. There is a relation between the volatile matter content of sludge and the ratio of the volume of centrifuge solids to solids by weight.
2. The use of the test must be based on standardization for each sludge analyzed.
3. Final results of total solids by weight determined in this manner are only approximate.
4. The preliminary choice of a factor of 4 for digested sludge at Buffalo[1] was approximately correct.
5. Smith's conclusions[2] that "the centrifuge test is probably satisfactory enough for rough plant control work, but as a matter of record, should be supplemented by actual solids determinations," applies to raw and digested sludge as well as activated sludge.

References

1. Water Works and Sewerage, **87**, p. 319 (1940).

2. Smith, J. I., Investigation of Rapid Methods for Sludge Solids Estimation. Sewage Works Journal, VI, 908-19 (1934).



Equipment Used in Centrifugal Solids Determinations

50 ml. tubes; centrifuge with speed control element and timing cut-off switch; raw and digested sludges before and after centrifuging.

RATIO OF SLUDGE DENSITY TO VOLUME

An Important Consideration in Operating

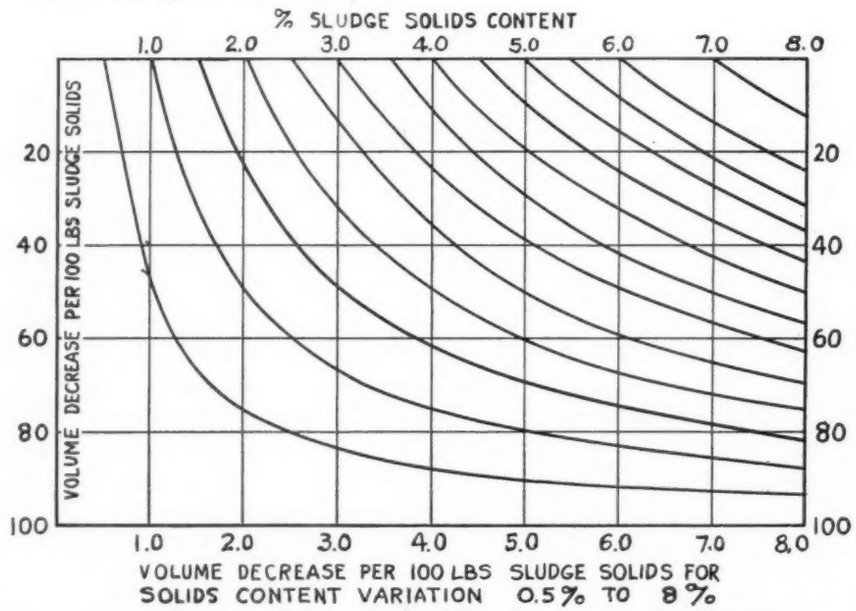
By GORDON J. WIEST, Chief Chemist

Chester Sewage Works, Chester, Pa.

THE variation in sludge volumes with solids content changes determines the most effective use of sludge handling and other treatment facilities in a sewage treatment works.

In this all important consideration it is, of course, the amount of liquid mixed with the sludge solids that determines the volume to be handled, and since the volume varies so markedly with the per cent of solid matter contained, this fact has important significance to the sewage works operator and engineer. The effect extends to the operation of digestion tanks, concentration tanks, aeration units, pumping and piping facilities, sludge storage, and other treatment units.

It becomes apparent that all the efforts of a sewage works operator to secure a more concentrated sludge contribute sizeable dividends to plant efficiency and operating expense, when one considers that a rise in moisture content by a mere 2.5% means 100% more liquid volume to be handled per one hundred pounds of sludge solids, when the water content rises from 95% to 97.5%. By the same token a sludge of 99.5% water, as against 97%, has a volume 500% greater. When using, as a base, the same quantity of solids to be handled, a digesting sludge of 95% moisture occupies just one half the space of a sludge of 97.5% moisture. The sig-



Curves Revealing Marked Effect of Sludge Volume Reduction Through Concentration.

Note that increasing solids content from 0.5% to 3.5% reduces volume to 1/6 original. This in the Activated Sludge Process is of great significance.

nificance of this matter is that the digestion period of the sludge may be doubled by what may look to be an insignificant decrease of only 2.5% water content. If a sludge with 95% moisture passes through a digester in a theoretical (calculated) time of thirty days, and the sludge becomes thinned to 97.5% moisture, two things happen to give a serious change in digester operation. These are:

(1) The solids pass through the digester in one-half of the theoretical time (actually more nearly one-quarter of the time, due to disturbance of solids, dilution, and intermixing of new and old solids).

(2) It will require approximately 100% more heat input to maintain a given temperature in the digestion tank because there is twice the volume of liquid to be raised to the desired temperature.

The marked changes due to a combination of these two effects are not hinted in the mere 2.5% more moisture content of the sludge which appears in the operating records. On the other hand if we recorded sludge concentration in terms of pounds of solids per 1000 gals., or the reverse, rather than percent solids, the volume relationship would become very much more evident to us in following operating records.

The relation of moisture content to the volume of sludge handled magnifies itself many times in activated sludge practice. For example, the difference between a sludge of 99.5% and 97% water is represented by a volume reduction of the magnitude of 6 volumes reduced to 1 and is of very real consequence and importance. The meaning of sludge volume decrease to an operator of an activated sludge plant may be easily evaluated upon a careful examination of operating data and any permissible measure of securing sludge concentration has high justification in improved operation and economy.

The accompanying graph shows the relation of sludge volume to solids content variations more fully than any number of words or further examples.

DETERMINATION OF HYDROGEN SULPHIDE BY SIMPLE METHOD

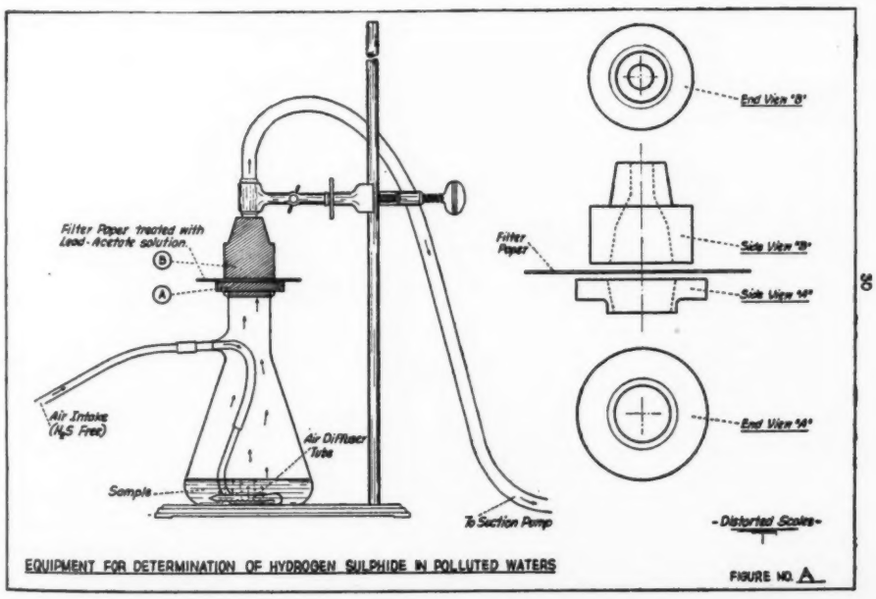
By GEORGE MARTIN, Superintendent of Sewerage

Green Bay, Wisc.

IN MAKING routine determinations of hydrogen sulphide in sewage, sewage gas, and polluted waters it was found that the procedure as described in Standard Methods was not satisfactory, due to the fact that polluted waters and sewage have an iodine demand. Therefore, a modified or special method of procedure was adopted. This special method is based upon the known fact that filter paper treated with a lead acetate solution will darken when placed in contact with hydrogen sulphide. It was found that by making a set of standards, with which any sample might be compared, consistent and fairly accurate results could be obtained.

The Apparatus

The apparatus necessary for making these determinations consists of a standard 500 ml. filtering flask, on the inside of which is placed an air diffuser made of a perforated aluminum tube connected to the flask's side tube by means of a rubber hose. On the outside of the side tube there is attached the rubber air intake hose. The lead acetate paper is held in place on the top of the suction flask between a rubber ring "A," which is a standard Gooch crucible holder for an ordinary two-inch funnel, and a standard Gooch crucible holder "B," as is ordinarily used with a filter flask. "A" and "B" are held together by a utility clamp fastened to a ring stand. The rubber hose which is attached to the glass tubing of "B" is connected to a suction device.



EQUIPMENT FOR DETERMINATION OF HYDROGEN SULPHIDE IN POLLUTED WATERS

FIGURE NO. A

The Procedure

In making a determination with this apparatus the sample to be tested is delivered into the flask directly from a pipette through the aeration tube. Air is then drawn through the liquid for two minutes and by so doing the hydrogen sulphide passes on up through the lead acetate paper, discoloring it. The amount of hydrogen sulphide is determined by comparing the colored lead acetate paper with the standards and converting the results into the desired units.

In order to operate this apparatus satisfactorily it is necessary that there be at least 100 ml. of liquid in the flask. Thus, if the sample being tested is high in hydrogen sulphide, it becomes necessary to dilute it with hydrogen sulphide free water. If it is desired to have the final results in p.p.m., this figure is arrived at by multiplying the color comparison in mg. by 1000 (mg. per liter = p.p.m.) and dividing by the ml. of sample used.

Example: Sample = 10 ml.
Volume of water added to flask ahead of the sample = 90 ml.
Color comparison = 0.05

$$\text{p.p.m.} = \frac{0.05 \times 1000}{10} = 5 \text{ p.p.m.}$$

Gas may be tested for hydrogen sulphide content by passing a known volume through the above described apparatus.

Test Papers and Standards

The lead acetate paper is prepared by soaking filter paper in a 10% solution of lead acetate and drying in an oven until approximately 10% to 15% of the moisture remains in the paper. The paper must then be kept in an air-tight container.

Standards are made from a solution of hydrogen sulphide prepared by generating hydrogen sulphide in distilled water from iron sulphide by the addition of dilute sulfuric acid, the solution being standardized by iodine titration.

[Note: The apparatus herein described won for the author first prize in the Gadget Contest conducted at the recent Convention of the Central States Sewage Works Association.—Ed.]

ACTIVATED SLUDGE BULKING*

Some Considerations as to Causes and Corrective Measures

By L. H. ENSLOW
Editor, "Water Works & Sewerage"

In presenting this informal discussion, and my own opinions with regard to causes of bulking of activated sludge, I shall also offer suggested corrective measures for bulking. The matter of "sticking my neck out," so to speak, gives me little concern if, by such willingness to expose myself, I can provoke more consideration and study of this most vexing and important problem of operation. And, in my belief, of plant design also.

What Constitutes Bulking?

The first question is—"What constitutes bulking?" When I first entered the sewage field I had heard of bulking sludge but I had no idea what it looked like. I thereafter discovered that there was more than one type of bulking. These types, in my opinion, represent two entirely different causes and effects. One is peptization of sludge floc and the other is really bulking (swelling) of sludge. True bulking of sludge means that the particles have become hydrophyllic. This means that they have taken up water, such as leather will, and swelled to the point that the gravity is so low as to cause the bulked sludge to rise in the final clarifying tanks. When in this condition, slight disturbance and increased velocities will cause it to pass out over the weirs of such sedimentation units. If you examine this sludge closely, you will likely also find that the particles are buoyed up by myriads of tiny gas balloons; i. e. very small gas bubbles of microscopic size. To cite an example, I have observed that salt water oysters subjected to fresh water will exhibit this same hydrophyllic phenomenon of absorbing water. One may say that, like the oyster, the sludge has become "bloated."

Let us consider some of the qualities and characteristics of an activated sludge beginning to bulk. Under the microscope you find that amongst the sludge organisms the protozoa have become sluggish. Instead of working vigorously, (for instance, the stems of bacticella and the like no longer coiling and coming back with a snap as they do when in a healthy condition) you will find that they are lazy and not at their job of assimilating bacteria and what not. I do not know whether they do assimilate anything other than bacteria, but at least they are not active when the sludge is ailing or, is it a case of "vice-versa."

Following this you begin to get peptization or bulking, as the case may be. Bacteria increase, and there is an oxygen deficiency. Nitrates are going down, whereas ammonia is increasing. There is a loss of characteristic brownish color of good activated sludge. In due time the effluent begins to take on the odor of hippuric acid ("hippo" meaning horse). However, the effluent is splendid for a time after bulking of the sludge begins to appear. It is crystalline clear for a while and represents a very excellent effluent. If one could "put the brakes on" at this point and hold the condition, he would have optimum activated sludge operation from an economy standpoint, and as high an efficiency as he could expect. However, the difficulty is that he cannot easily stop the bulking-ball that has started rolling.

The next thing that happens is that the bulking becomes very pronounced. With increase in sewage flow, the sludge blanket is disturbed, and much sludge goes over the weirs into the stream. The liquid portion of the effluent, even yet, is not bad but becomes so in time, if the cause of bulking is not corrected.

What Causes Bulking?

Now let us consider some of the causes of real bulking (swelling), as distinguished from peptization of flocs and milky effluent, such as poisoning of bacteria as enzymes may produce. The universal answer is the deficiency of dissolved oxygen reserve and nitrates in the aerating units or in the final settling tank. The latter may be as important as the former. In other words, the way I look at it, the problem becomes a question of oxygen "banking." Picture an aeration tank (sketched on the black board). Whether by air diffusion mechanically or by air blowing, in the aeration tank liquor you are "banking" dissolved oxygen. With this banked oxygen you can meet demand notes by withdrawing or checking. The notes are the oxygen demand "notes" of the sewage plus that of the sludge in the mixed liquor. If your balance is steady, or on the increase, and your withdrawals are gradually on the decrease through the aerators, you will always have at all points in your "oxygen bank" a residue of dissolved oxygen on which you may draw. Such means solvency and will keep you from going absolutely oxygen bankrupt. Assuming this condition can be maintained, you will never find yourself "in the red"—at least as to performance if not in respect to costs. If you do overdraw your oxygen account but within an hour or so you replace the overdraft, adding perhaps a little surplus, you are still safe from your principal debtor whose initials are B.O.D. In commerce the criterion, of course, is how quickly and adequately you are able to do your banking, that is, how quickly you can make your deposits to meet the on-coming drafts or checks. Just so it is with the balance between oxygen reserve and oxygen demand in an aeration unit, which spells solvency, or bulking bankruptcy.

Another analogy may be made in citing two runners—one a strong runner and one a weak runner. Should the strong runner stub his toe just as he takes off from the starting point, he may have a hard time to overcome the set-back and may even come in, a limping loser. Overcoming such a handicap, even against weak competition, is frequently very difficult. So it is in financing, that is, in making up bank deficiencies; and, so it is in the activated sludge process in making up oxygen deficiencies which reach serious proportions near the influent end of the aeration units.

The rapid oxygen demand of the sewage, as I stated, is the critical thing. This occurs at the inlet end of the aeration unit and represents the sudden demand notes drawn on the oxygen in the bank. I have seen activated sludge plants operating very nicely on very strong sewages, as long as the input remained on an even keel. On the other hand, I have seen activated sludge plants confronted suddenly with varying organic loads, and the process has gone all to pieces with startling rapidity. One would not think that these periodic loadings could disrupt the process the way they do. Of course, what I have said is particularly true of small plants. In large plants it takes much more to cause trouble than in smaller ones, for the reason that your bank is stronger and the "balance" is not so easily upset.

Sludge vs. Liquor.

Too much sludge carried in the aeration tank has an effect similar to too much of an organic load in the sewage coming in. However, in my opinion, the sludge loading does not begin to compare with the influent loading in importance. The reason is that it is a more stable load and is subject to control. It is not flashy unless somebody permits the sludge to become partially septic; then, of course, it has an explosive oxygen demand which is disastrous. The return of supernatant liquor from digesters is a tremendously bankrupting practice as many have learned. More about this later.

Another cause, I think, of activated sludge bulking or perhaps of moderate bulking is a lack of inorganic matter in the sewage. I refer now to material like iron, salts, silt or clay, and other materials which tend to give weight and coalescence to floc of any sort, whether activated or not. As a matter of fact, I consider the activated sludge process to be as much of a natural coagulation process as it is of an oxidation process. The first stages of coagulation and adsorption are by far the most important stages in activated sludge, and if we could chop it off at some point before nitrification sets in (and hold it there) we would have the greatest amount of work for the least number of dollars for operation. Unfortunately, no one has found the formula for this procedure, the nearest to it being the Guggenheim biochemical process which involves a combination of chemical precipitation and bioflocculation.

I might mention that recently there has been considerable work done on the use of silica as a coagulation aid. Perhaps many of you have heard that in water treatment practice silicates may be

* *A paper presented before the Ohio Conference on Sewage Treatment; reprinted from the 12th Annual Report of the Ohio Conference.*

used for improving flocculation with alum and iron, and so in sewage treatment it may well be that something of this nature will be found to play a part in activated sludge coagulation. I cite one indication that silica may have a distinctive bearing. I have frequently observed cases where clay or silt enters sewers as a result of rainstorms. And, almost immediately the coagulation phenomena of activated sludge, the settleability of the sludge, and consequently the important sludge index, seem to improve. I am wondering if perhaps the colloidal silica content of clays may not have a bearing on activated sludge coagulation as it does on alum and iron coagulation. I consider this an interesting problem for some student or researcher to undertake; namely—"The Effect of Various Inorganic Compounds on Activated Sludge Behavior."

Another reason for the bulking of sludge is too little oxygen input in the sludge reaeration channels, if reaeration is practiced. In other words, your bank balance is decreasing rapidly and can decrease extremely fast if you do not keep well ahead of the sludge demand, so to speak. Sludge may have (and frequently does have) a rapid oxygen demand as it comes from the final tanks. In other words, if you are returning your sludge slowly to obtain a concentrated return, you are tending to build up in that sludge an increased and a rapid oxygen demand. Should you not have enough oxygen to take care of the demand immediately, and not enough carrier liquor in which to "bank" this oxygen, you will never catch up. By putting into the inlet of the aeration unit an oxygen deficient sludge you have lost ground before the mixed liquor enters the aeration tank and, in my opinion, that is the reason for the difference in arguments, pro and con, for reaeration of sludge. A new theory is that reaerated sludge must be kept nourished with fresh sewage input. Some will tell you that reaeration is worthless and that it is really harmful, whereas others say that they cannot get along without it. I believe it to be just a matter of the balance of oxygen reserve as to whether or not an operator needs or does not need reaeration of sludge. The British practice is to reaerate and return very thin sludge. The freshness and thinness of their sludges may account for their successes with reaeration.

Another point is the ratio of settleable solids to non-settleable solids in the sewage. I mention this point for the following reason. In Great Britain one of the remedies in sludge bulking is to bypass the long period primary tanks, thus diverting more suspended solids into the aeration units and also securing a fresher sewage, with benefits later to be cited.

Grease and oil have an effect on sludge bulking. Grease or oil mix in with the activated sludge floc and coat the particles, affecting the specific gravity of the sludge if nothing else. Many engineers think it has considerable bearing on the bio-activity of the sludge. Studies now under way will tell us more about this later, but grease separation appears definitely beneficial.

There has been a suggestion that yeast is harmful and results in bulking; that is, yeast from breweries and other places. Some British authorities seem to think yeast is very harmful. I think possibly the yeast growth is the index of something else that is worse. I refer to the oxygen demand, and more particularly to the demand rate of the waste which contains the yeast; but this again is a personal opinion and needs verification. Where yeast is, there is usually a lot of organic matter with it.

Then we come to filamentous bacterial growths, of which we hear so much, such as sphaerotilus and leptothrix. In paper mills they call these growths "slime." I will speak a little more about filamentous growths later. They may be the cause of bulking, but I do not believe they are the direct cause. I think they are indexes, again, of a deficiency of oxygen which is the direct cause of bulking.

Then, of course, there is carbon dioxide. Gas liberation, carbonaceous fermentation and acid production unquestionably have an effect on bulking. Septic sewage and supernatant digester liquor, in my opinion, is probably one of the most serious factors contributing to bulking in the greatest number of plants.

The Effect of Septic Sewage.

I was very much interested in an article that appeared in the July, 1938, issue of "Water Works and Sewerage." Written by Dr. Heukelekian, of the New Jersey Experimental Station, it more or less fights this battle for for me. I have claimed a lot of things that were bad of septic sewage, but I did not know what the New Jersey authorities have revealed—namely, "That once sewage has become septic it will take up oxygen only one-half as fast (approximately) as the same sewage in a fresh condition." In this revelation many will be surprised and take on an increased respect for septic sewage and supernatant liquor. In his studies of the effect of septic sewage on activated sludge, Dr. Heukelekian took septic sewage, boiled it to kill all life and then reaerated it. He found that the same sewage in a fresh condition, treated in the same way, would take up twice the oxygen; that is, would take the oxygen at twice the *rate,* the latter being the important revelation. The amount of oxygen required is not nearly so important as is the rate at which it is required, and the *rate* at which it will be dissolved and "banked" in the liquid phase.

With the above in mind, septic sewage reaching a plant in hot weather reduces the capacity of the storage reservoir of dissolved oxygen by about fifty per cent. For instance, Dr. Heukelekian found that in twenty minutes of aeration, fresh sewage (boiled) would take up 3 parts per million of oxygen (approximately) as against 1.8 parts per million for *septic* sewage treated in the same way. You will note that this is almost two to one. But this is not the whole answer. The important consideration is, that if this happens every twenty minutes from the influent end of the aeration tank through the effluent end of the tank, and if the aeration period is six hours, the effect is considerably multiplied, and interest on the deficit is compounded. Let us put it this way. The dissolved oxygen "balance" is in pretty bad shape before you get to the end of the tank. You have not accumulated anything, because the oxygen is going out at a rate you cannot control, and this rate is faster than it can be deposited. This constitutes about the most interesting disclosure I have seen in the way of an explanation of why it is desirable and many times necessary to avoid septic sewage. We do know that in hot dry weather more than one activated sludge plant operator goes home at night and prays for rain. When he gets rain he knows he is on safe ground, at least temporarily. In my opinion, dilution is one of the best corrections for septic conditions, and it is not a far cry to recommend that a handy creek be bled into a sluggish sewer in hot dry periods.

Supernatant liquor from digestion tanks, if discharged to the inlet of the plant, causes an effect similar to septic sewage, but there is so little of it that you do not begin to feel the cumulative effect that you would if all of the sewage is septic. However, the fact is that supernatant liquor does cause serious upsets of the process. Further, it probably encourages the growth of organisms in the sewage which I believe those of normal activated sludge do not like as associates, and likewise adds toxins.

Peptization of floc can be caused by different things, but you usually find that this condition is caused by a poison of the decolloidizing elements or organisms in the sewage and sludge. In other words, the clotting effect is hurt and you do not get efficient flocculation. Peptization results in a whitish milky-looking effluent.

Correctives

Now consideration may be given to possible correctives and there are several of them. Some of them work and some do not. Some work here; some work there; and some work nowhere. The first thing to try is more air—if you have it. The next thing is lesser amounts of return sludge, reducing the amount of solids in the sludge rather than the volume. If anything, you usually have to increase the volume of return sludge. The third measure, of course, is less sewage. That last seems to be a universal corrective because by-passing has been the most prevalent method of correcting difficulties at activated sludge plants. Adding clay is another method and the use of chlorine still another.

I was extremely interested in another phase of Dr. Heukelekian's paper. His conclusion reads, "The dissolved oxygen level in the activated sludge process is the resultant of the supply and demand of oxygen. The supply is governed by the method and rate of aeration available." Further quoting from his conclusion he says, "Another factor that influences the level of dissolved oxygen is the temperature. As the temperature increases, the amount of oxygen that can be dissolved in the liquor decreases, and at the same time a greater demand exists due to increased biological activity. Thus, the critical periods in the operation of an activated sludge plant appear in the warmer season." If you add to this condition septic sewage, the operator's difficulties are further increased. On both scores the mixed liquor naturally will not dissolve as much oxygen.

Again quoting, "Theriault and McNamee have estimated that 35 per cent of the dried activated sludge is represented by bacterial cells. * * * The bearing of these generalizations on the maintenance of dissolved oxygen in the activated sludge process is obvious. As long as aerobic conditions are maintained, the process of aggregation of sewage colloids will take place, resulting in a well clarified effluent and an active sludge. When there is no dissolved oxygen present the process of aggregation will cease, the opposite process of dissolution will take place, breaking up the aggregated sludge floc."

Dr. Heukelekian then concludes by saying, "Until more definite information is available, indicating that with higher dissolved oxygen concentration a much more rapid purification is brought about, a minimum of 0.5—1.0 p.p.m. dissolved oxygen maintained at all times and in all sections of the aeration tank should be considered as the most economical range."

Other correctives have been seasonal treatment of industrial waste to reduce the load on the plant. Lime have been employed for pH correction, but I will say that my experience has been that the use of lime offers very temporary relief. It does seem to shrink the sludge temporarily, but you soon find that the effluent becomes milky and conditions become unsatisfactory again.

Other methods than by-passing include reaeration, more rapid sludge return, which I have touched on, thickening of excess activated sludge going to the digesters, and stage digestion of sludge, which gives a less objectionable supernatant liquor.

Sludge Thickening.

As to sludge thickening, it was first developed at Los Angeles and later used at Phoenix, Arizona, where it proved a "life-saver." Topeka practices it as does Columbus, and Baltimore is including it in the design of improved works. When sludge thickening is practiced, the sludge is not returned to the raw sewage for settling in the primary tanks where it may become degraded and much of it passes over into the aeration tanks. To my mind, it is extremely questionable practice in activated sludge treatment, and poor economy to return this material to the sedimentation units. A good many people have argued contrary to this, but I have observed many activated sludge plants, have studied them, and have thought about them a lot. When I see this bulky, half-rotten sludge which was put into the tanks as good activated sludge, which laid on the bottom as long as it could and which finally is swept through to the aeration units, I am certain it has a tremendous oxygen demand. It has a tremendous chlorine demand and anything that has a tremendous chlorine demand likewise has a very high oxygen demand. I do not know whether the organisms contained have any effect on the aeration tanks or not, but I do feel that the needless load on an activated sludge plant, caused by this manner of handling sludge, is absolutely unnecessary. It is necessary to take all the load coming to the plant (the sewage) but why should you take a good activated sludge and let it go through partial digestion and put it back into the aerating tanks again during periods of peak loadings?

"Freshening."

Sewer flushing or sewer dilution has always been helpful where septic sewage is the cause of the trouble. I have often said that any operator is fortunate who has the trunk sewer to his plant passing under a brook or stream. By knocking a hole in the sewer and by fitting it with a suitably constructed valve, he is able to realize the value of sewage "freshening" and sweeping sewer flows. It may even pay to install pumping equipment and pump water from a stream, or he might even pump some plant effluent back into the incoming sewage. In my opinion, it may cost less to pump water into the sewer than it does to pump air for aeration purposes and there is little question but that the operator will sleep better at night.

Sludge Return Control.

Now, about sludge return reduction. This seems to be an extremely important item at times. First, the operator keeps down his solids and, second, he draws his activated sludge back fast enough so that he gets more fresh liquid to dissolve more oxygen in the "banking" process. Many of you may be surprised to know that at some plants the return sludge is 50 per cent to 100 per cent by volume. Now why do the operators do this? It is more or less for the same reason that I would like to have a creek pass over the trunk sewer to any activated sludge plant which I would have to operate. The increased return sludge volume naturally will reduce the aeration period, but a 6-hour aeration period does not necessarily mean a thing in the world. One may get better results in two and one-half hours if he knows how. More liquid is delivered to the aeration units, thereby supplying a "blotter" that will absorb more oxygen and hold that oxygen in a higher concentration (probably three times as much) than is possible with strong or septic sewage. Naturally, the total oxygen demand is the same but the operator has been able to put more "money" in the bank. While the total draft remains the same, he avoids oxygen bankruptcy. The whole point is this: Put something into the aeration tanks that will dissolve the oxygen input and then furnish the tank with all the oxygen (air) you have.

There are some operators who say that they want to have a "sludge reserve" for return at augmented rates when troubles appear. Well, all I have to say is this: They are just inviting a lot of trouble. It is ideal (on paper) to have a big reserve sludge tank that can be kept thoroughly activated all the time from which the so-called "shock troops" may be obtained. I know one plant (London, Ontario) working on this basis, but it costs the municipality a lot of money. Actually what those fellows do in London is to return super-aerated sludge to the sewage in the aeration tank. This aerated sludge acts rapidly. When I heard of the theory of zeolite action by sludge, I thought right away about the London scheme, because the operation at this plant is probably as good an example of such action as anything I have seen. Sludge is reaerated for about twelve hours. The contact with the sewage is less than two hours. There is no question but that a good plant effluent results, but the power requirement certainly reflects the high cost of sludge reaeration. And, every so often something has to be done to retard the activity of sludge in the reaeration stage.

Chlorination.

Now this discussion has developed to the point at which I will refer to chlorination and its uses pertinent to activated sludge. First, considerable can be accomplished by chlorinating up-sewer to suppress septic action in sewage. This has been demonstrated better perhaps in Los Angeles County than anywhere else. There it was impossible to treat more than about one-half the sewage flow until up-sewer chlorination was instituted. It was really remarkable how readily the sewage quality was modified and the entire flow could be handled once chlorination was established.

Then, there is return sludge chlorination, which was really "born" in Ohio, and credit goes to E. E. Smith of Lima and to M. W. Tatlock of Dayton for having initiated this procedure.

After Smith and Tatlock told us about chlorination of return sludge the next place at which we heard of its use was at Lancaster, Pennsylvania. I may say, that too much chlorine in the chlorination of return sludge results in peptization, and a "milky" effluent is an indication of such. However, return sludge chlorination certainly has possibilities, as has been demonstrated at other important plants. At Lancaster, aero-chlorination is now being used for grease separation and Mr. Weist, superintendent, has written me that he believes aero-chlorination is better for his purpose than return sludge chlorination, for the reason that it separates grease which previously he had found in his activated sludge. In other words, it is doing two jobs, so to speak.

Phoenix, Arizona, has been practicing concentration of waste sludge for some time, sending it directly to the digester and chlorinating the digester supernatant liquor for return to the aeration units. This has done a lot of good, but now, in addition to this practice, the Phoenix authorities have gone to chlorinating the return sludge.

Now why does this chlorination of return sludge work? I again wish to emphasize the fact that I advance *probable* reasons, largely personal opinions. First of all, bacterial control is accomplished, that is, control of the growth of saprophytic organisms, not the organisms we see on 37 degree plates but those that take up so much oxygen. In this group are the bacteria of fermentations and the sulphate splitters. They produce a lot of CO_2, a lot of hydrogen sulphide, and a lot of trouble for a lot of operators. I liken their presence or absence to cold weather versus hot weather conditions. In other words, if you can suppress bacterial activity through your aeration tanks, these organisms are not present to draw upon the oxygen and to dissipate it rapidly. There is less oxygen demand in the absence of these organisms. For one, I do not believe that saprophytic organisms, as a general rule (certainly not anaerobic organisms), have a place in a sewage plant, other than in the digestion tanks.

The second reason why chlorination of return sludge works is that control is had of filamentous growths. I frankly believe sphaerotilus and other slime forming organisms which we find in activated sludge (like pH and dissolved oxygen) furnish an index of conditions. I believe the deficiency of oxygenation is the real cause of bulking and that filamentous growths, since they will not grow unless a low oxygen balance is had, are principally an indication of a deficiency of oxygen. Chlorine suppresses the rate of dissolved oxygen disappearance and maintains the oxygen balance. In doing this, filamentous growths are controlled. I have seen these biological growths in streams below sewer outfalls, as many of you have, but they disappear just as soon as you begin to get to a stable or balanced oxygen condition. The activated sludge process, with controlled application of chlorine to return sludge, does not "stub its toe" at the inlet end of the aerators and, therefore, deos not come limping down

to the finish line. This practice has accomplished much at Lima, Ohio; Phoenix, Arizona; and Houston, Texas. As a matter of fact, I believe that at Houston the greatest benefits of all have been accomplished by chlorination of the return sludge.

In this connection I will first read from a letter which I recently received from D. Travaini, superintendent, relative to an experience at Phoenix, Arizona. In part he says: "In April of this year we had a beautiful case of bulking. Our convention (Arizona Sewage Works Association) was three days off and we weren't happy with our results. The aerators were so full of filaments that the sludge had completely lost its identity. We ran an emergency chlorine line from our chlorinator to our reaerator and in five days our bulking was completely gone. One hundred pounds of chlorine per day did the trick. The chemical dosage (based on volume of sludge returned) amounted to 5 to 6 p.p.m. of chlorine. Since then we have played around with chlorinating our sludge. Our plant is up to design capacity, but in spite of this fact, by using 75 to 100 pounds of chlorine per day, we have been able to eliminate one aerator from service at a saving of about $50.00 per month, in favor of chlorine over power. We had a serious breakdown in the aerator in question so we had to follow the procedure mentioned but it worked, so we planned to continue this practice."

Houston, Texas, has for some years suffered with an overloaded activated sludge plant. Although at this time the plant is in the process of being enlarged, the boys down there are due a lot of credit for keeping the present plant on as even a keel as they have. I wish to read from a paper by William Pralle, assistant city engineer in charge of sewers, at Houston. This paper, which deals with the operation of the sewage treatment plant, was presented before the Texas Water Works Association. I quote from the paper as follows:

> "Another advantage of an activated sewage treatment plant is that with a little larger operating cost, from about $1.50 to $2.00 per M.G. according to the delivered cost of chemicals, the plant capacity can be increased without spending a young fortune for permanent construction of extensions.
>
> "To make myself clear, I do not mean to hold back on proper capacity to meet average daily flow of activated sludge plants, but do believe in having the plant equipped with a chemical unit to be used in emergencies, and at times when the plants appear to be overloaded.
>
> "The South Side Sewage Treatment Plant in Houston, employing the activated sludge process, has been increasingly overloaded in both aeration and sedimentation capacity for several years. The result has been that the general difficulty, commonly referred to as 'bulking,' was almost continuously present. In the Spring of 1937 a plan for experimentation was adopted, whereby chlorine and chlorinated copperas, or either one of these chemicals as found best by experience, was to be applied during the treatment process.
>
> "Chlorine alone has been applied to the returned sludge at Houston, just prior to mixing with the incoming raw sewage, since May 16, 1937, and the resulting improvement in the plant effluent has been very satisfactory.
>
> Only a portion of the data collected is in form for presentation here, but the following indicates the general improvement so far realized in the plant effluent.
>
> "The average 5-day B.O.D. of the plant effluent for four months prior to chlorine application was 66 p.p.m. and the filterable suspended solids 96 p.p.m. The average B.O.D. determined daily for the two weeks, May 16th to June 1st, was only 37 p.p.m., or almost half. And, the filterable suspended matter for the same period was likewise cut practically in half.
>
> "Chlorine was applied at the average rate of 5.34 p.p.m. to the returned sludge. At this particular plant the volume of returned sludge is, for operating reasons, much higher than is usually practiced in per cent of raw sewage treated. The average aeration time at this plant is practically 2½ hours, so that the reduction of the volume of returned sludge, made possible by chemical treatment, has produced part of the benefits.
>
> "During chlorine application microscopic examination made daily has shown a distinct reduction in number of filamentous organisms in the sludge. * * *
>
> "It has further been definitely found that effective control of chlorine application is necessary for best results, and that over-chlorination will produce undesirable conditions from which recovery is slow."

Then, in his letter referring to an operating record chart attached, Mr. Pralle replies to questions asked by me as follows:

> "You have referred to some of the shortcomings of the chlorine application, or conditioning of returned sludge. Excepting the added cost, the only comment we can offer at present is that a definite 'overdosage' is possible and should be guarded against. The limits of the amount which can be applied with benefit have not been determined, but our experience has shown that a very cloudy appearance of the effluent can be obtained and this has been relieved only by reduction in the chlorine quantities.
>
> "During construction incident to enlargement of our North Side Plant, chlorine application has been in progress for about 90 days. The data obtained are now being compiled, and these promise to given even more satisfactory information.
>
> "Questions of 'Cause and Result' have been found which have not been answered to our satisfaction, so that all comments are welcome. For instance, attention is directed to the greater difference between suspended solids and B.O.D. content of plant effluent during chlorination than prior to chlorine application. (Mr. Pralle is referring to the fact that B.O.D of the effluent improved more markedly than the suspended solids reduction would indicate.—Ed.) Our laboratory methods in all instances have been the same, and two questions are: (1) What has happened to the B.O.D. of those suspended solids which tests indicate are present in the effluent? (2) If the B.O.D. test of the effluent has been vitiated by this small amount of chlorine (as some seem to think is the case) why, then, is the B.O.D. reduction still evident in the analyses of water of the receiving stream below the plant?"

The reason I have read excerpts from Mr. Pralle's paper is to call attention to the fact that as long as the plant is performing better, the effluent is good, and the dissolved oxygen conditions downstream are good, an operator need not be concerned as to the exact technical explanation of the chlorine effect. However, it would be interesting to have more exact knowledge of the effects. This paper, with the accompanying analytical data, indicates that when you have difficulty in keeping your oxygen input up to a satisfactory level, it is a pretty good idea to return a thin sludge at higher rates, than a thicker sludge [longer removed from the aeration cycle) in lesser volume. The interesting thing with reference to the data at the Houston plant is what happened to the B.O.D. of the plant effluent when chlorination of the return sludge was stopped. As Mr. Pralle has stated, after the discontinuance of return sludge chlorination for a period of ten days, just about ten days with chlorination was required to get the plant back in a satisfactory condition. These results and Mr. Pralle's experiences at Houston strengthen my belief that there is a very tangible "something" to the chlorination of return sludge.

[Since this discussion was presented, a very large and important Eastern plant has been employing return sludge chlorination with beneficial results, even during winter months. Another plant (South) also reports good effects, as measured by visible appearances and a more "even keel" type of plant performance, although there is little in the way of analytical data to reveal just why such is the case. Both plants have started low, raised the chlorine dosage gradually until floc peptization appeared and then dropped the dosage back to a non-wasteful point.—L. H. E.]

For a Splendid Article Dealing With

OPERATION AND CONTROL PRACTICES IN ACTIVATED SLUDGE

By T. R. HASELTINE

See pages 284-289 in the Magazine Section

SLUDGE BLANKET DETECTOR AND TURBIDIMETER

By DON E. BLOODGOOD

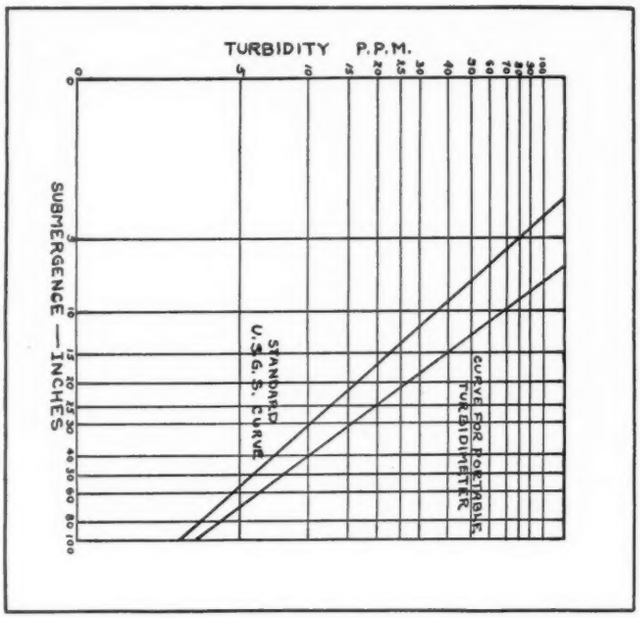
Engineer, Sanitation Plant, Indianapolis. Ind.

To a sewage plant operator, the appearance of the effluent is the best indication of the effectiveness of the treatment process. But to convey to the superintendent an accurate description of the appearance, in writing, is difficult. A superintendent should know each morning the hourly condition of his plant during his absence. He also wants his operators to be able to tell him how one day's effluent compares with that of any other day.

To supply this information in the most concise, yet explicit form, an instrument has been constructed at the Indianapolis Sewage Treatment Works which can be used as a portable turbidimeter and a sludge blanket detector. It consists of an 1¼ inch I.D., 0.065 wall, 2 FH aluminum tube 68 inches long with a sleeved brass collar on the bottom into which the brass moisture proof lamp case screws. There are four ports in the cap which admit water but exclude all outside light. The glass disk is held against a rubber gasket making a water tight joint. In the 1/32 inch metal disk there is cut a ¾ inch cross of 0.012 inch opening with the center closed off by a piece of metal not larger than 3/32 inches in diameter to blank out the bright spot caused by the bulb filament. The light reflector is painted with aluminum paint. The operation of the lamp is identical with the ordinary two cell flashlight except for the self-operating mercury switch. This mercury switch is in the base cap of the lamp case and is constructed in a case of sealing wax. The sealing wax was first run into the base cap and sloped to a small depression in the center. A short piece of No. 24 platinum wire was set on each of opposite sides of the depression with the ends about ⅛th of an inch apart. One wire is grounded to the base cap and the other is connected to a copper plate, making a connection with the battery through the coil spring. Only a very small drop of mercury is needed in the switch. After the mercury is placed, a heavy paper disk is set over the top of the mercury pocket and the cap is filled with sealing wax.

In use, the instrument is submerged to a point at which the cross disappears and then the scale on the side of the tube is read by looking in to the six-sided mirror of the float, in one plane of which the figures will show. The mirrors are set at a 45° angle with water proof china cement in sycamore or any other tough light wood.

The portable turbidimeter was calibrated by getting the submergence in effluents of known turbidity. This data when plotted on logarithmic paper gave a curve somewhat different than did the data of the standard U.S.G.S. turbidity table, as can be seen by the accompanying graph. The scale for any turbidimeter constructed could be obtained from the graph of the calibration data



Graph for Converting Submergence Into Trubidity Reading

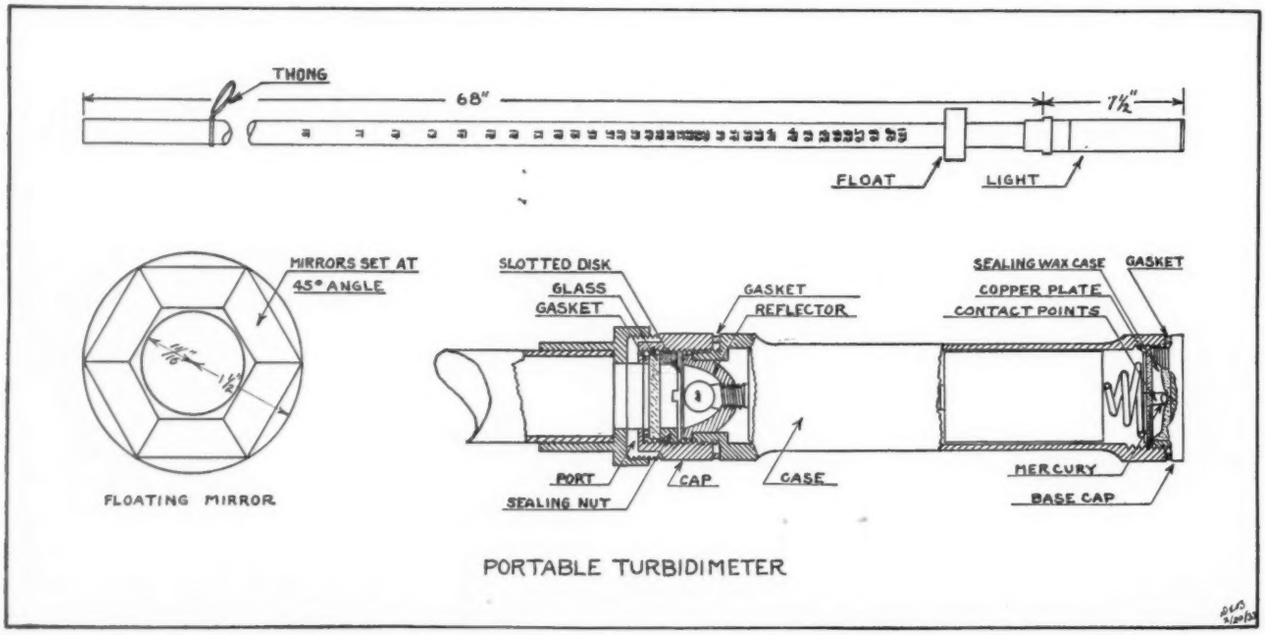
or it could be calculated by developing a formula for the particular curve, similar to the formula of the standard curve:

$$\log y = -1.106598 \log X + 2.6570$$

in which y= p.p.m. of turbidity and X = submergence in inches. The curve for the portable turbidimeter herein described is:

$$\log y = -1.35652 \log X + 3.2085$$

The shortcomings of the portable turbidimeter are appreciated. The turbidity increases at lower levels of the basin so that the readings obtained may not describe the nature of the actual effluent and yet be indicative of plant operation. At Indianapolis, however, the information obtained through the use of the portable immersion turbidimeter has been very helpful in connection with plant operation.



Portable Turbidimeter and Sludge Blanket Detector Used at Indianapolis Sewage Treatment Works

SERVICING OF POROUS AIR DIFFUSERS

By FRANK C. ROE

Director of Sanitary Sales, The Carborundum Co., Niagara Falls, N. Y.

To maintain the high efficiency of porous diffuser plates and tubes of the type used for aeration in sewage and water treatment plants, their operation should be checked regularly. Partial clogging of the porous structure may occur for a number of reasons, thereby decreasing the effectiveness and increasing the cost of aeration.

The writer and his company have made a study of the various methods of servicing diffusers necessary to maintain their efficiency for a reasonable life.

The most immediate and positive indication of obstruction within the diffuser structure is an increase of compressor or blower pressure necessary to supply a given quantity of air. Visual examination of the aeration tank or tanks will also disclose non-uniformity of diffusion which may be due to a partially clogged condition. This is a practical determination but not so conclusive as the first.

Diffusers may become clogged on either the air side or on the liquor side; that is, on the top or bottom of plates and on the outside or inside of tubes. Both classes of clogging may be experienced simultaneously, but are avoidable to a great extent.

Liquor Side Clogging

1. *Suspended Solids*: Perhaps the most common type of clogging is caused by interruption of aeration during which the solids in water, sewage, sludge or mixed liquor settle and the water content filters through the diffusers into the air duct. Most of the solids in suspension are intercepted at the diffuser surface, but a definite proportion, depending on the pore size, will enter the top 1/16 to ⅛ inch of the structure. When aeration is resumed all of these particles will not be blown out of the structure and cumulative clogging results.

Maintenance of continuous air delivery, at least to some degree, is the positive way to preclude this trouble. Temporary cessation of the air supply is not impossible with modern equipment, but the usual auxiliary blowers with standby power units and inexpensive automatic control equipment will largely eliminate shutdowns.

Care should also be taken not to over-design in the matter of diffuser area. Not less than one cubic foot of air per minute should normally be discharged per square foot of diffuser area. Insuring a higher rate, so as to maintain good air velocity through the pores as well as uniformity of diffusion from the entire diffuser area, is better practice still.

2. *Organic Growth*: Another form of liquor side clogging is growth of bacterial and protozoa life in the uppermost portion of the porous structure. This may be attributed, at least partially, to non-uniformity of diffusion. All of the diffusers controlled by a single valve may not have similar permeability ratings, or the individual areas of any particular diffuser plate or tube may not be uniform one with another.

As suggested, it should be possible to avert clogging of this nature by careful installation and selection of plates or tubes. All units controlled by a single air valve should have a similar permeability rating within limits of 0.5 cu. ft. or less. Uniformity of individual diffusers depends upon precision and perfection in manufacturing.

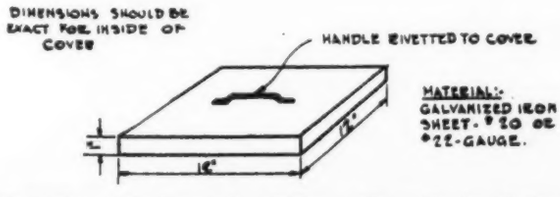

DIMENSIONS SHOULD BE EXACT FOR INSIDE OF COVER
HANDLE RIVETTED TO COVER
MATERIAL:- GALVANIZED IRON SHEET. #20 OR #22-GAUGE.
12"
12"

Plate Cover for Protecting Diffuser Plates During Setting

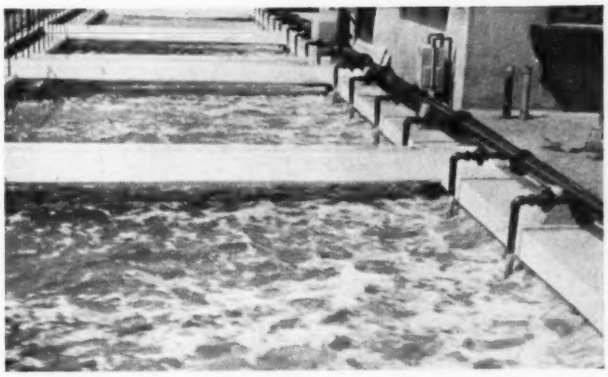


Plate 1—A Section of Aeration Tanks (Sewage Treatment Plant, Golden Gate Park, San Francisco), an Example of Uniform Diffusion

3. *Miscellaneous*: Very often protection from cement grout (or other material used to install plates), dirt, debris, etc., is not provided during installation or when tanks are empty, and appreciable surface clogging results. A plate cover (see sketch) should be used to shield plates from cementing materials during installation, and other protective measures should be observed when tanks are empty.

Air Side Clogging

1. *Dirt in Air*: Air containing a high quantity of soot or other impurities is a major source of clogging on the underside of diffuser plates or inside of diffuser tubes. Selection of effective air filters and care in locating the air intake are obvious preventatives.

The thought should be injected here that diffusers of higher permeability than the type used during the early days of sewage aeration are undoubtedly subject to less clogging of this nature because of relatively larger pores through which many of the fine suspended particles pass rather than stop. It is doubtful if the air bubbles released from higher permeability diffusers are very much larger than the bubbles discharged from the earlier low permeability grade of diffuser. The fact remains that higher permeability diffusers have not been less effective than those of lower ratings previously specified.

2. *Oil in Air*: Reciprocating compressors are now rarely used in sewage aeration, but the oil which they force through air lines is responsible for pronounced diffuser pore plugging. Fortunately, the low pressure required for sewage aeration permits the use of rotary blowers of the centrifugal or positive displacement type. If reciprocating units must be used for any reason, an oil trap or filter of some kind should be used between the compressors and the diffusers.

Certain types of primary air filters depend on the use of an oil for cleaning or renovating. In this operation it is recommended that a partial wash with a solvent be given after the oil treatment so that oil will not be blown free and carried through the diffusers.

3. *Air Pipe Rust or Scale*: It is generally recognized that cast iron pipe as a material for air lines is sufficiently resistant to corrosion from moisture to be considered to have almost an endless life. Genuine wrought iron is likewise considered satisfactory. Galvanized or sherardized steel pipe would be considered suitable for relative short periods of life, while ordinary black iron pipe or steel is not suitable.

In spite of the consideration given to this phase of air pipe design, there is evidence that some air side clogging is caused by iron oxide in the form of rust particles and scale.

There are economic considerations involved in preventing this source of clogging. Aluminum and copper pipe have been used

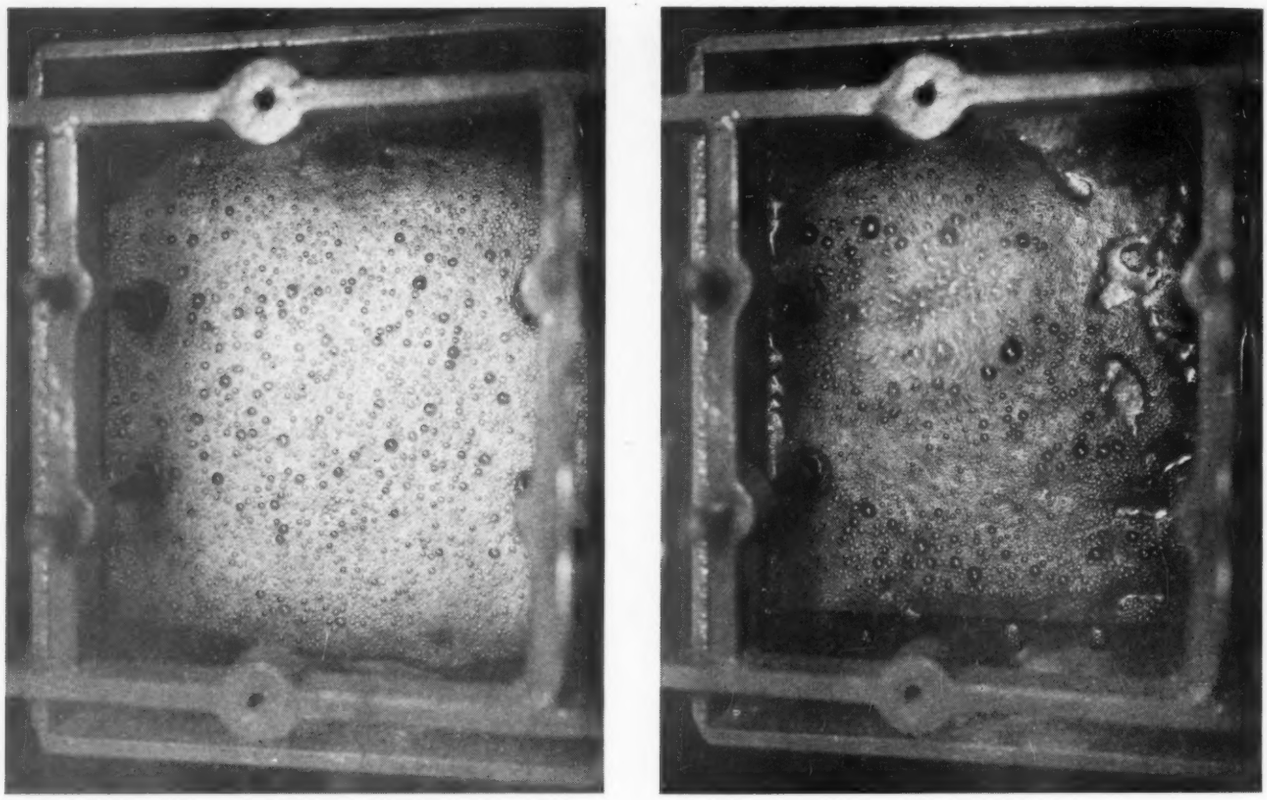


Plate 2—An Illustration of Good Uniformity of Diffusion on the Left; Poor Uniformity on the Right. (Photographs Taken Looking Down on Diffusion Plates in Testing Apparatus)

for the smaller air lines and are recommended along with other types of corrosion resistant pipe. However, if the use of such pipe raises the installation cost appreciably it should be balanced against the estimated cost of diffuser servicing and replacement.

4. *Miscellaneous*: Air lines left in a dirty condition after installation can cause clogging of considerable magnitude. The remedy is obvious. Cast iron diffuser plate containers may cause the same difficulty as does iron piping, but to a lesser degree. Mr. William M. Piatt has avoided this possible source of trouble in designing containers for some of his plants in North Carolina, by using aluminum container linings. At other plants the entire plate holder is to be of aluminum.

Restoration of Diffuser Efficiencies

Because of the diversified types and degrees of clogging experienced in the 100-odd activated sludge plants in the country, it is natural to expect that there are many methods of cleaning in use. Lacking information on the subject, plant superintendents and operators have, more or less successfully, devised and developed individual methods of their own.

Plate Cover for Protecting Diffuser Plates During Setting

The writer's company, in addition to considerable experimental work in the research laboratories. has fostered a survey among those in charge of plants throughout the United States and Canada, believing that many practical methods of diffuser cleansing would come to light. The response to our inquiries and the cooperation received has been most gratifying and has made it possible to present the outline to follow. Some of the methods have been improved, amplified or supplemented as the result of certain research work which we have conducted.

Methods employed in diffuser cleaning can be divided into two general classes; viz., methods applicable to diffusers in place (suitable largely to liquor side clogging) and methods which are adaptable only to removed diffusers. Tubes are cleaned for the most part by the latter method because they may be quickly and easily removed. The methods to follow are not given in an order to indicate preference.

Cleaning Diffusers in Place

1. *Caustic Treatment*: Clean aeration tank and surface of diffusers thoroughly with hose stream and leave about ½ in. of clean water over plates, providing the slowest practical air diffusion during this period. Dissolve about 1/10 lb. commercial lye crystals over each square foot of plate and then shut off air. Allow solution to penetrate plate (10 to 15 minutes), add more clean water, and then turn air on a maximum rate. (Note: This method is chiefly applicable to removal of organic compounds.)

2. *Sand Blasting*: Dry plates thoroughly by draining containers completely and blowing out porous structure with air

Plate 3—Diffuser Plates Stacked in Furnace for Burning-Out of Organic Matter. (More Clearance Between Plates Preferable; See Method 14)

applied at high rate. Sand blast plate surface with usual type of sand blast equipment, using "Blastite" Grain. Remove not more than 1/32 in. from surface, *maintaining maximum air discharge during the operation.* One minute or less is required to clean a plate by this method.

3. *Surface Spalling*: Dry plates by draining containers and blowing out porous structure with air at high rate. Apply oxy-acetylene flame with oxygen at 10 lbs. pressure and gas at 5 lbs. pressure. The flame should be applied almost parallel to the diffuser surface, i. e., at as acute an angle as possible. Remove from .010 in. to .015 in. of diffuser surface. Sweep off and rub surface smooth with a Carborundum rubbing block. Sweep off particles again. Leave air on during entire operation.

4. *Burning Out Surface*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, saturate each plate with one quart of alcohol and apply heat with blow torch. Dry and brush off surface.

5. *Acid Washing and Scrubbing*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, apply a 30 per cent solution of hydrochloric (muriatic) acid to the surface liberally and allow same to penetrate somewhat before turning on air at a low rate. Scrub with a stiff brush, using more acid if necessary. Follow with a clean water wash and scrubbing with a wire brush, continuing air discharge at a somewhat higher rate. (Note: This method is chiefly applicable to removal of inorganic compounds.)

6. *Vacuum Cleaning*: This method has not been proven but was suggested by authorities at the Milwaukee Sewage Treatment Plant, where a trial was intended. A vacuum pump was to have been used with a suction inlet of small area which would be held closely against and moved back and forth across the diffuser surface to be cleaned.

7. *Rest*: Dry plates by draining containers and blowing out porous structure with air at high rate. Allow diffusers to rest while dry for a week or more. (Note: The theory of this treatment is that the change of conditions will cause the bacterial and protozoa growth in the porous structure to die.)

8. *Chlorine Treatment*:* Introduce a strong dose of chlorine into the branch air line leading to each diffuser assembly for several minutes during a low rate of air flow. Following by blowing out diffusers with the maximum possible rate of air flow. (Note: This method is chiefly applicable to removal of organic compounds and carbonates.)

9. *Steam Backwashing*:* Dry diffusers by draining and blowing out porous structure with air at high rate. Introduce steam into the branch air line at 10 lbs. pressure and scrub diffuser surface simultaneously with a stiff brush.

10. *Water Backwashing*:* Introduce clean water into the branch air line under pressure of 15 to 20 lbs. per sq. in. Scrub diffuser surface simultaneously with a stiff brush.

Cleaning Removed Diffusers

11. *Acid Pickling*: Wash diffusers with water (use hose and brush). Set in a vertical position and allow to drain and dry as much as possible. Soak in 30 per cent solution of hydrochloric or nitric acid for four hours. Wash with water. (Note: Use Hydrochloric acid if it is desired to dissolve inorganic compounds and nitric acid if it is desired to oxidize organic compounds.)

12. *Caustic Treatment*: Place diffusers in vessel containing a 10 per cent solution of sodium hydroxide (lye) and boil for about one hour. Remove from this solution and wash thoroughly in boiling water. (Note: This method is only applicable to partial removal of organic compounds, chiefly fats, which are saponified by the caustic soda and then dissolved in hot water.)

13. *Sandblasting*: Dry diffusers thoroughly (preferably in an oven of some kind) and sandblast (Method 2) on either or both sides, as required. It is recommended that, where practicable, the diffuser be inserted in a container which will make it possible to force air through it at a high rate during the operation. This will eliminate any clogging by the dust created.

*Methods applicable to tubes or plates and of some benefit also in cleansing the air size of diffusers.

14. *Burning*: This method is applicable to diffusers of the fused crystalline alumina type. Place diffusers in a furnace or kiln in any convenient position, leaving a space of not less than ½ in. between units. Raise temperature gradually during 10 hours to about 1000 deg. Centigrade and then allow to cool gradually. The cycle should take at least 16 hours. Fuel of any kind is satisfactory, but care must be taken to avoid impingement of flame against diffuser surfaces. At Decatur, Ill., gas from sludge digestion was used.

Selection of Method

Every plant operates under conditions peculiar to itself, which will prove a factor in the ease or difficulty of diffuser servicing and the methods of cleaning which can be, or should be, used. One method may work satisfactorily in one place but be wholly unsatisfactory in another place or at another time.

In general, methods used on diffusers *in place* are not better than 75 per cent effective and range down to as low as 10 per cent where the clogging is almost wholly on the air side. Methods of cleaning removed diffusers are much more effective and are from 60 to 95 per cent effective. It is usually a combination of two or more methods which will produce the best result; because, any single method is not a cure-all.

The combination of causes and degree of clogging vary greatly and therefore it is not possible to give a rating of effectiveness to each method of restoration. It can be stated, however, that acid pickling of removed diffusers (Method 11) followed by burning in a furnace or kiln (Method 14) is 90 to 100 per cent effective, regardless of type or degree of pore plugging. This combination is therefore, recommended where serious clogging exists.

A simple improvised furnace can usually be built at a sewage plant to refire diffusers, other considerations being satisfactory. Where this work proves impracticable in the field, the writer's company will use its kilns at Niagara Falls for refiring when requested. Such arrangements would offer an added advantage in that refired diffusers can easily be retested and rated so that they may be properly re-installed thereafter.

The above suggests the consideration of providing a simple permeability testing apparatus at sewage treatment plants which would be useful in re-rating removed diffusers which have been cleaned at the plant. Even though original markings are retained, which is doubtful, all units will not respond equally to the cleaning method employed and will have a new permeability rating which should be determined when re-installation is made.

For acid pickling (Method 11) a wooden tub is satisfactory. The caustic treatment requires an iron kettle because of the boiling operation. Workmen should use precaution in these methods by wearing rubber gloves, aprons, etc. Tongs can be used to handle diffusers.

Where existing plate containers do not permit simple mechanical plate removal, a joint composed of sand in the bottom ½ in. and cement grout in the top, is recommended for setting plates in holders. This will save time and avoid plate breakage when removal becomes necessary. Plates so installed should be set with a lime mortar under the supporting edges to insure an even bearing.

Conclusion

The practice of regular servicing should be stressed if the diffusers in any plant are subject to a known source of clogging. If this is done, whether it is apparently needed or not, the permeability will be maintained indefinitely, in all probability, and one or more of the simple and least costly methods of revivification can be employed.

Because of the several potential sources of diffuser pore plugging which exist, and because many of these cause air side clogging, the use of plate containers which permit easy removal of plates is recommended. Ease of removal and replacement is one of the important advantages of diffuser *tubes* for smaller plants. In this connection the new "swing" diffuser and stationary diffuser equipment offered by the Chicago Pump Company is highly recommended.

Diffusers of high permeability are less subject to clogging because of larger pores. They operate on a slightly lower air pressure than low permeability diffusers. Because of these advantages, and the fact that effectiveness of aeration is not decreased (compared to that provided by low permeability diffusers), plates of a higher rating are recommended.

PURGING AIR DIFFUSER PLATES WITH CHLORINE

By W. M. FRANKLIN, Superintendent
Water and Sewage Plant, Charlotte, North Carolina

The five aeration units at the Irwin Creek Sewage Treatment Plant, at Charlotte, N. C., are of the ridge and furrow type, equipped with diffuser plates. Manometers register the cubic feet of air per minute being delivered to each aeration unit. A master air-meter records the total quantity of air applied.

In the early summer of 1938 the diffuser plates in all the units became so badly clogged that it was impossible, even with two blowers in service, to get enough air through them to maintain proper aeration. All units were then cleaned out, as rapidly as they could be spared from service, and the diffuser plates scrubbed with muriatic acid. This had been the practice since the beginning of plant operation. All but two of the units responded reasonably well to this treatment. Units, No. 1 and No. 5, became clogged again after a few weeks operation. The acid cleaning was repeated in these two but with no better success. The normal average delivery of air per unit with one blower in operation is about 700 to 750 cubic feet per minute. The delivery of the diffusers in No. 5 unit was down to an average of 450 ft. with one blower in service, and with two blowers in parallel an average of 750 ft. could be maintained—(see Fig. 1). Since it was impossible to increase the air delivery in these two units by throttling the other three, and thus increasing the pressure of the air in the header feeding the diffusers, we were in something of a "mess."

At this time the plant load was heavy and the removal of one unit from service for a period long enough to empty and clean was extremely hazardous.

We decided to follow a suggestion previously made by L. H. Enslow of the Chlorine Institute. This suggestion was to add chlorine (as gas) to the air headers leading to the diffusers, with the idea that the chlorine would destroy algae growth in the plates, and might attack other clogging materials.

We first viewed this plan with alarm, fearing that the presence of chlorine gas in the air lines might cause corrosion, especially in the small feeder lines. Finally it was decided to try chlorine anyway. A tap was made in the header feeding No. 5 unit and chlorine fed into the air flow at the rate of about 17 lbs. per day.

In Fig. 1 the delivery of the diffusers in No. 5 aeration unit, in cubic feet of air per minute, has been plotted from August 22, 1938, through Oct. 9, 1938. Dotted lines indicate the period during which two blowers were operating in parallel, the solid lines indicating the period during which only one blower was in operation. Note that on Sept. 15 chlorine was fed for about four hours at the 17 lb. per day rate with two blowers operating. After the chlorine was cut off the two blowers remained in service the 18th. At this time one blower was removed from service and on the 19th the chlorine application was continued until the 150 lb. cylinder was exhausted on Sept. 25. The second blower was put on the line on the 24th with the idea that the increased velocity through the plates might help in opening up the pores. On the 30th normal operation was resumed with one blower.

Note the increase in air delivery during the period following the first "shot" of chlorine until the end of the curve on Oct. 9.

Actually, the chlorine brought about an increase of approximately 66% in air delivery with one blower in service and 53% with two blowers in service, as is shown by the curve. Needless to say we were so well pleased with the results that we immediately cleaned No. 1 unit with one cylinder of chlorine getting equally as gratifying results as was the case in the No. 5 unit.

At this date March 1, 1939, the air delivery of the diffusers in both Unit No. 5 and Unit No. 1 is about 750 cubic feet per minute and no detrimental effects from the application of chlorine have been observed.

It is our theory that the action of the chlorine not only cleaned the surface of the diffuser plate but also cleaned the pores *from the inside out,* removing organic matter from interior pores of the plate which could only otherwise be removed by a heat treatment, or long soaking in an acid bath.

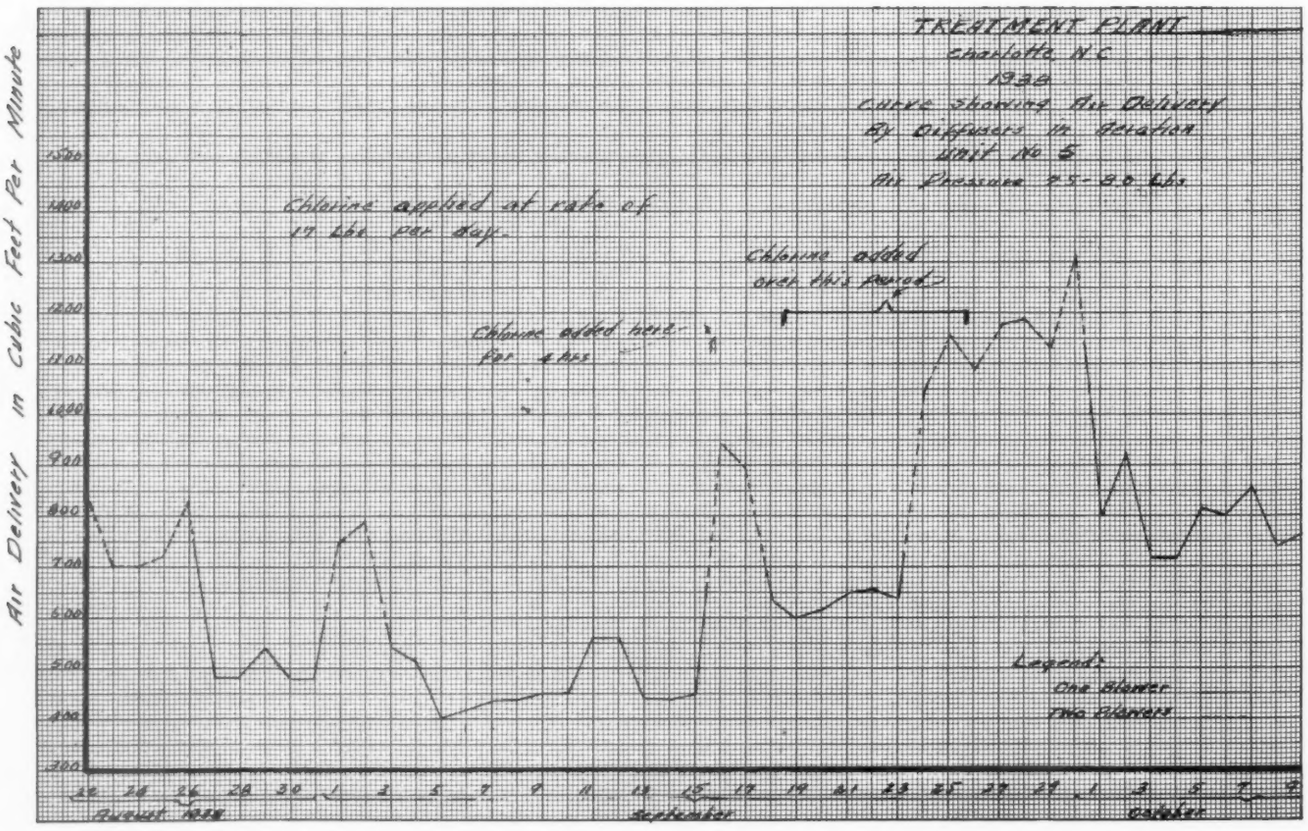


Fig. 1.—Graph Showing Change in Air Delivery Before and After Treatment of Plates With Chlorine Gas, in Situ

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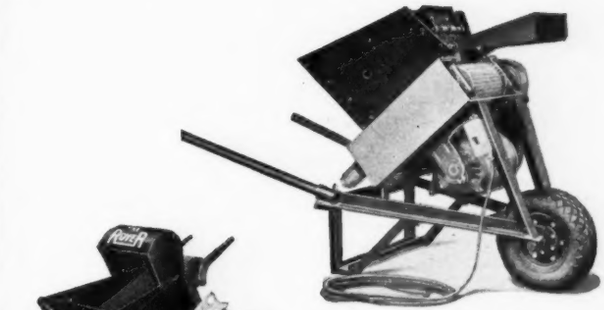

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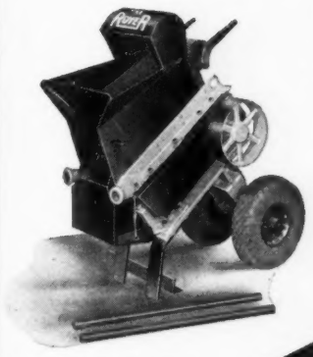

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FERTILIZER AND FERTILITY

Values of Sewage Sludge

DR. WILLEM RUDOLFS
Chief, Dept. of Water and Sewage Research
N. J. Agricultural Experiment Station
New Brunswick, N. J.

THE use of various types of sewage sludge as sub-grade fertilizer or soil builders has been advocated for many years. Enthusiasm to use this by-product of sewage treatment has come mainly from the layman, but soil technologists and soil scientists continue to wonder why sludge is not returned to the soil for its plant food and fertility value. (Note that a distinction is made between plant food content and fertility value.) Many farmers, gardeners, florists and green-keepers have tried the material, but frequently have stopped after some years.

Sanitary engineers in general have looked at the sludge problem as a question of destruction of noxious matters rather than conservation of values. Sewage plant operators have tried to stimulate its use. There is an increasing tendency to find ways and means to utilize sludge, principally as a fertilizer filler or for soil improvement through direct application.

An inquiry to determine why the material is not used on a larger scale, especially from smaller plants, or why the use has been discontinued, seems to indicate several reasons which can be summarized as follows: (1) insufficient knowledge of the value, (2) improper use of the material or insufficient preparation, (3) excessive claims made by the seller, or (4) lack of interest by the seller.

From a hygienic standpoint there is *no problem* if the sludge is used in a proper manner. A rather extensive inquiry made to determine whether ill-effects have been observed on animals or human beings, shows that where land disposal has been practiced for many years no disease or epidemics have occurred. This is probably due to the fact that users of large quantities of sludge have taken proper precautions. As a rule fresh sludge has been used only on forage crops and plowed under after application. Heat dried activated sludge and heat dried digested sludge appear to be safe for any reasonable use in agriculture, horticulture or floriculture, while well digested air dried sludge appears to be as safe as manures.

What Is the True Value of Sludge?

Determinations of the values in sewage sludges have chiefly been a matter of testing for the principal fertilizer ingredients (nitrogen, phosphorus and potash), while sometimes the organic matter content is taken into consideration. Users of sludge for agricultural or horticultural purposes have repeatedly called attention to the fact that the results obtained could not be entirely accounted for by the mineral or plant food constituents. The better results have been variously explained on the basis of: (1) the organic matter content of the sludge results in an increased moisture holding capacity of the soil, preventing retardation of growth or wilting during dry weather; (2) an improvement in the soil structure, especially in clay, allowing more air to enter and subsequently a stimulation of oxidation or organic matter by the soil organisms; (3) introduction of large numbers of bacteria and protozoa, resulting in a speeding up of decomposition, the introduction of micro-organisms, such as molds, into the soil, making the nutrients more available for the plants; (4) introduction of certain minerals needed for plant growth; absence of weed seeds, which may utilize the available plant food.

On the other side of the picture is the discontinuance of the use of sludge after several years on account of plant injury. The reasons advanced for plant injury have been mainly: introduction of poisons in the soil which were present in the sludge (certain industrial wastes); high grease content resulting in water logging and production of organic acids; burning of plants resulting from acidic decomposition products which make the soil acid.

Sludge Constituents—Major and Minor

Until a relatively short time ago it was assumed that only ten chemical elements (nitrogen, phosphorus, sulfur, calcium, magnesium, potassium, iron, carbon, hydrogen and oxygen) were indispensable for the growth of higher plants. Many other elements, if found effective, were regarded as plant stimulants. In 1914 Prof. Mazé at the Pasteur Institute in Paris, showed that other elements were necessary. Not much attention was paid until in 1923, when Miss Warrington at the Rothamsted Experiment Station in England found that boron was essential for beans and several other plants. Only during the last few years has it been found that a number of plants can not complete their growth cycle without minute quantities of boron, copper, zinc, manganese, possibly molybdenum and several others. These "minor," or "accessory," or "micro-nutrient" elements have a remarkable effect on various phases of plant growth. Iron, for instance, plays a role in oxidation, copper has been reported as

Preparation and Conditioning an Important Consideration in Marketing
Compare the handleability and saleableness of the lumpy product on the left as removed from the drying beds, and the uniformly granulated and aerated product turned out by a well known sludge disintegrator

essential in certain oxidase systems; manganese is essential to respiration and to nitrate reduction in plants; zinc may be important in the change of carbonic acid to water and CO_2; certain metal deficiencies produce chlorosis of varied types of green plants.

A compilation of the chemical composition of sludges, including the main fertilizer constituents and the "minor" elements, is given in Table I. For comparison it should be kept in mind that the average fertilizer ingredients of barnyard manures are about 2 per cent nitrogen, 1 per cent phosphorus (P_2O_5) and 1.5 per cent potash (K_2O). It is evident that in addition to the main fertilizer ingredients, small quantities of "minor" elements are present in the sludge which may play an important role in plant growth. The quantities of minor elements are relatively small, so that danger of poisoning the soil is absent. The quantities of lime salts present in the sludge varies with the hardness of the water supplies and the manner of sludge treatment. The amount of lime salts expressed as (CaO) may be as low as 2 per cent and as high as 12 per cent on a dry basis.

A Potato Crop—With and Without

From the same area, in a field side by side, potatoes on left were fertilized with 400 lbs./acre of Toledo's air-dried digested primary sludge, marketed under the name "Tol-e-Gro." The yield was just 200 per cent more than the pile on right not fertilized.

TABLE I

Average Chemical Constituents of Sewage Solids and Sludges*

Element	Fresh Solids	Digested Sludge	Activated Sludge
Total Nitrogen (N)	4.50*	2.25*	6.20*
Phosphoric (P_2O_5)	2.25	1.50	2.50
Potash (K_2O)	0.50	0.50	0.75
Silica (SiO_2)	13.80	27.60	8.50
Iron (Fe_2O_3)	3.20	6.00	7.20
Aluminum (Al_2O_3)	2.10	4.30	3.20
Calcium (CaO)	2.70	5.70	1.70
Magnesium (MgO)	0.60	1.00	1.40
Manganese (MnO)	0.02	0.04	0.03
Sodium (Na_2O)	0.80	1.50	1.00
Titanium (TiO_2)	0.06	0.10	0.08
Copper (CuO)	0.02	0.05	0.05
Barium (BaO)	0.05	0.10	0.06
Zinc (ZnO)	0.01	0.04	0.03
Lead (PbO)	0.10	0.20	0.20
Nickel (NiO)	...	...	0.005
Cobalt (CoO)	0.0002	...	0.0002
Sulfur (So_3)	1.2	2.5	2.90
Chlorides (Cl)	0.50	0.50	0.50
Chromium (Cr_2O_3)	...	...	0.20
Arsenic (As_2O_3)	trace	trace	0.013
Boron (Br_2O_3)	...	...	0.0115
Iodine (I)	...	...	0.001

*All figures being % of each ingredient on the dry basis.

Humus Value

As a soil builder the humus content of sludge is less than that of barn-yard manure, because the ash content is greater, but still is of considerable value in sandy and heavy clay soils.

The crude fiber (cellulose, lignin, etc.), being complex insoluble carbohydrates, resist bacterial decomposition and remain longer in the soil (TableII). Most of the so-called total organic matter gradually disappears, but is of importance from the standpoint of humus accumulation and moisture holding capacity of the soil. Soils which retain a higher moisture content, usually support a greater variety of plants and allow the plants to continue their growth even during dry spells.

Fats and greases are important chiefly because they make the sludge lump and interfere with the desirable uniform distribution of the sludge. Also, because grease decomposition produces acidic compounds, resulting in acidic soils. It is our experience that most of the injurious effects that may be chargeable to sludge application for a number of years are due to the accumulation of acids in the soil. The first few years these acids have a tendency to make insoluble plant foods present in the soil more available; hence, produce better results than might be expected from the sludge alone. After a few years the available insoluble plant food has been reduced and the soil becomes more and more acid. Certain plants, which desire a neutral or only slightly acidic soil, are retarded in their growth and finally are injured by the accumulated acidity. The simple application of agricultural lime (carbonate of lime) neutralizes this acidity. For best results in the long run, a judicious lime application every 3 or 4 years prevents a good deal of trouble. The fact that this simple remedy often has been overlooked accounts for reluctance of farmers and greenhouse growers to use sludge after a few years' trial.

Growth-Promoting Substances

Increasingly, it is recognized that plants do not synthesize vitamins or their precursors as a philanthropic act for the benefit of animal or man. These substances have a function in the plant itself. The substances are generally classified as growth-promoting substances, since they may induce root development, stem elongation, cell swelling, ripening of fruit, stimulate germination and flowering, and produce other responses. Farm yard manure and decaying vegetable matter have been shown to contain various growth-promoting substances. Tests made for the presence of some of these substances in sewage sludges are summarized in Table III.

The quantities of growth-promoting substances required to affect the growth of plants are extremely small. Comparatively large applications of artificially produced compounds may even cause injury or retardation. Indole and skatole derivatives appear to be among the most effective growth-promoting substances. Indole and skatole, as well as butyric, acetic and propionic acids, are produced during decomposition of sludge and can be expected to be present. The presence of various growth-promoting substances give to sludges a higher *fertility value* than indicated by a mere chemical analysis, which reveals only the principal *fertilizer ingredients.*

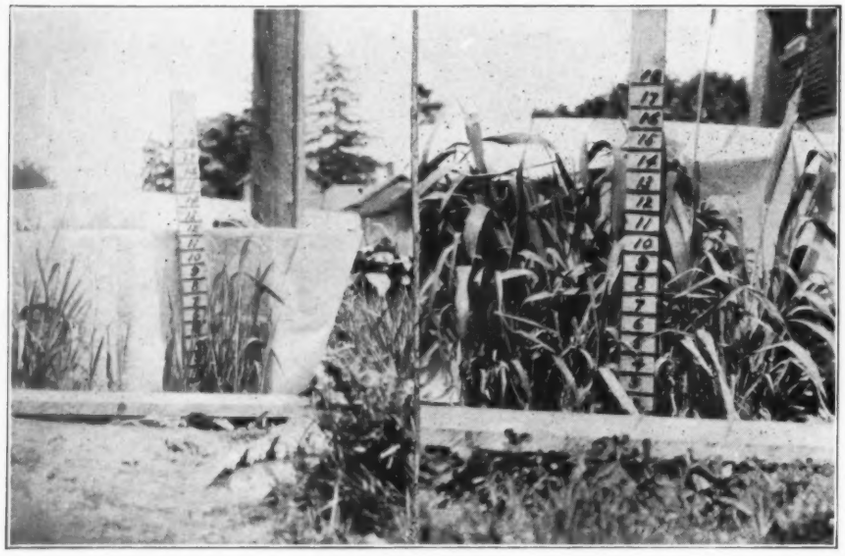
Practicing farmers have maintained for years that mineral fertilizers "burn out" the soil. What is meant is that mineral fertilizers stimulate the destruction of organic matter, making the plant food, plant stimulants and hormones available in greater abundance. This results in increased crop yields, but also gradually reduces the stored-up fertility of the soil. Thereby,

TABLE II

Composition of Sludges

Constituent*	Fresh Solids	Digested Sludge	Activated Sludge
Organic Matter	60-80*	45-60*	65-75*
Total Ash	20-40	40-55	25-38
Insoluble Ash	17-35	35-50	22-30
Pentosans	1.0	1.50	2.10
Grease and Fat (Ether)	7-35	3.5-17.0	5.0-12.0
Hemicelluloses	3.2	1.6	.....
Cellulose	3.8	0.6	7.0†
Lignin	5.8	8.4	.....
Protein	22-28	16-21	37.5

*All figures being % of each constituent on the dry basis.
†Includes lignin, etc.



A Small Grain Demonstration
In this instance, a 40-day growth of barley

A Corn Crop
On this field 200 lbs./acre of pulverized air dried digested primary sludge was uniformly spread. The owner is now a real sludge booster; the reason being apparent

TABLE III

Presence of Growth Promoting Substances in Sludges
(Relative Amounts of Single Substances)

Substance	Fresh Solids	Digested Sludge	Activated Sludge
Skatole, p.p.m.	1.2 -7.8	traces	none to traces
Indole, p.p.m.	0 12-7.0	0.5-1.0	0.0-0.05
Ascortic acid (Vitamin C)	++++	++++	++++
Carotene	+++	++	+
Tryptophane (free)	++++	+	++
(combined)	++++	++	+++
Tyrosine (free)	++++	+	++
(combined)	++++	++	+++
Phenyl compds.*	++++	++	++
Naphthyl compds.†	—	—	—

*As benzoic acid; † as ∝-naphthol.

the soil becomes poorer. The value of farmyard manure is in replenishing the organic matter, "minor" elements and growth-promoting substances. Its application is of importance, therefore, in making the soil gradually richer. A similar function can be ascribed to sewage sludge. Since sewage sludge contains only relatively small amounts of the principal fertilizer ingredients crop yield cannot be as great as from mineral fertilizers; but, like other improved animal manures, it improves the soil and will continue to do so if acidity is checked by lime applications.

Sludge Enrichment or Sludge Filler

The addition of mineral fertilizers to enrich sludge results in a more complete product. Not only are the necessary major plant foods present, but the required "minor" elements and growth-promoting substances are available. This combination produces a balanced fertilizer and, also, a soil builder. This balanced product gives higher crop yields without loss of soil fertility. Such a balanced product is of especial value for sandy and clay soils. The response of rich loamy or peaty soils to this balanced product should be less and it explains partly why experiments conducted with various crops in different soils may appear to be contradictory.

The amount of organic matter present is of importance, because of its favorable effect on the absorption capacity of the soil, and is of further interest because it is the carrier for organic nitrogen, which aids bacterial decomposition and becomes available to the plant when needed.

Crops and Plants Benefited

A compilation of plot experiment results and actual practice of crops and plants which have been benefited from sludge applications (Table IV) indicate that a number of grasses, root and leaf crops, trees and shrubs respond to sludge. The list is incomplete, because only those plants have been included where sludge was of *definite* value. Cases where the value was doubtful or contradictory have been disregarded. Sludge has been found to be of particular value on lawns and greens. It does not cause "burning," but small applications of lime are necessary from time to time.

TABLE IV

Crops and Plants Which Have Benefited from Sludge Applications

Field crops and fruits—
- Corn
- Wheat
- Rye
- Barley
- Turnips
- Grass
- Beets
- Mustard
- Potatoes
- Tobacco
- Cotton
- Apples
- Citrus fruits
- Strawberries

Flowers—
- Roses
- Carnations
- (Many annual flowers respond to sludge, in some cases leaf growth is more stimulated than is flowering.)

Truck crops—
- Squash
- Tomatoes
- Turnips
- Pumpkins
- Beets
- Carrots
- Radishes
- Parsnips
- Onions
- String beans
- Lima beans
- Lettuce
- Spinach
- Sweet corn
- Cabbage
- (and others)

Trees and shrubs—
- Maple
- Ash
- Birch
- Chestnut
- Prunus
- Cornus
- Jasminium
- Hydrangea
- Berberis
- Spirea
- Daphne
- Cotoneaster
- Taxus
- Several broad leaf evergreens

The amount of sludge applied varies with the crop. For field crops the application varies from 6 to 10 tons per acre, but additions up to 40 tons per acre have produced good results. A number of nursery men have reported good results with young trees and shrubs with sludge used in a manner and in quantities such as would be used if the material were barn-yard manure.

Over-All Value

The *fertility* values together with the *fertilizer* value of sewage sludges may be summarized in general as follows:

In addition to relatively small amounts of the principal fer-

tilizer ingredients, sewage sludge contains "minor" chemical elements and growth-promoting substances essential and necessary for proper plant growth. It prevents depletion of humus and is capable of increasing the fertility of the soil. It improves the soil structure in general and increases the water holding capacity of sandy soil in particular. The value of sludge is not the same for all soils, neither is it the same for all crops. Except for growth observations there is no adequate measuring-stick for revealing the over-all value of sewage sludges as soil improvers and growth promoters—in short, their fertility values as contrasted to their limited worth as fertilizers, based on the chemist's analysis alone.

THOSE PLUS VALUES OF SEWAGE SLUDGES — IN SHORT, "FERTILITY"

(*Well Demonstrated in 13 Years of California Experience*)

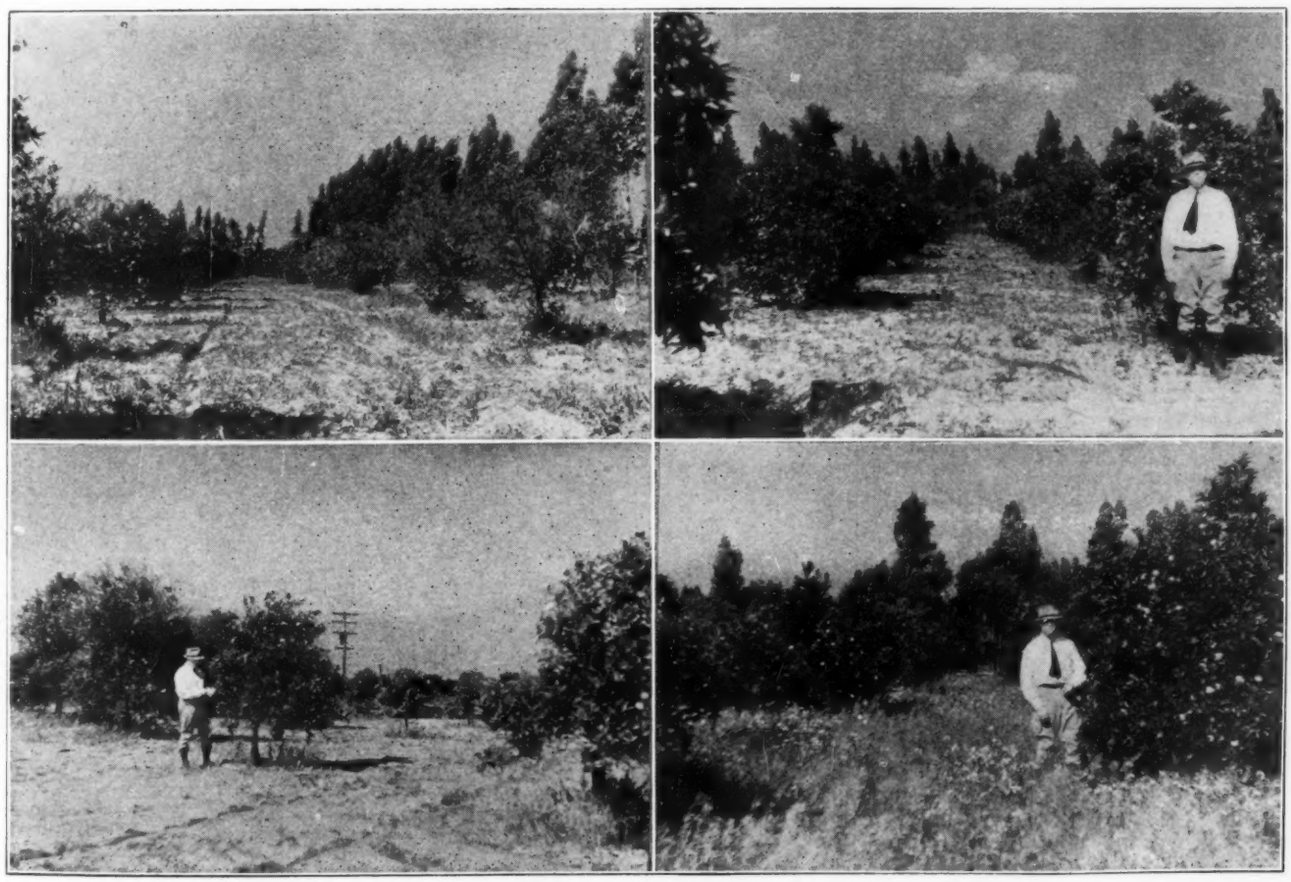
Excerpts from a Discussion

By A. M. RAWN
Chief Engineer and General Manager
Los Angeles Sanitation Districts
(Associate Editor, Water Works and Sewerage)

IT has long been recognized by those who have used, or observed the use of sewage sludge as a fertilizer that the value of the sludge in that capacity appears greater than the sum total of its fertilizing constituents, and that its influence in crop culture goes over and beyond anything which the customary analyses as applied to other fertilizers may indicate. Although there is nothing mysterious about these somewhat obscure factors they have not been generally recognized in their true form heretofore. Therefore, the story by Doctor Willen Rudolfs, in the December issue of WATER WORKS & SEWERAGE, in which he separates out values (fertilizer), which react to laboratory analysis, and those (fertility) which are determinable only by observing plant reaction to the fertilizer, is timely and important and should have a beneficial effect upon the future use of sludge.

Some California Experiences

In Southern California there are three sewage treatment plants, each producing a type or grade of sewage fertilizer quite different in composition and characteristics; nevertheless all are find-



A Further Testimonial for Sewage Sludge.

Two Valencia groves that are thriving and two adjacent plantings of identical age that are not. The two upper views are but 200 ft. apart. The only known difference in treatment is that the grove on the right has been fertilized with shredded digested sludge cake and kiln dried fine-screenings for the past several years. The lower views are of two groves separated only by a road. That on left has had no fertilizing; that on right has been fertilized solely with Los Angeles fine screenings. These groves, of the same stock, were planted simultaneously. When considering various experiences, and these long term results with digested sludge, one is convinced that it possesses a plus value which the expressive and inclusive term "Fertility Value" most aptly defines.

ing a ready acceptance in the culture of citrus groves and to some extent in other crops. Each appears to have characteristics, not measurable by laboratory yardsticks, which give them the extra values about which Doctor Rudolfs speaks.

The Pasadena Tri-cities sewage disposal plant has successfully pioneered the sale of dried activated sludge. Not only the orange grower but the fertilizer company appears to have accepted "Nitroganic" as more than an ordinary crop producer. It has been used for years successfully as the *sole* fertilizer on many extensive orange groves.

The joint disposal plant of the Los Angeles County Sanitation Districts is a large producer of dried digested primary sludge, a material containing between 2 and 3 per cent nitrogen and a comparatively low content of phosphoric acid and potash. Its organic content ranges from 50 to 55 per cent. This material is sold to a fertilizer agency on the open drying beds at a rate which yields the districts about $2 per dry ton. The buyer stands the expense of removing the sludge cake from the beds. It is macerated and sold in bulk to orange growers for about $7.00 per ton at 40 per cent moisture. The material bears the trade name "Nitrohumus" and is advertised as an organic sewage fertilizer. (Figured on a dry basis the price of $7.00 per ton in bulk for a digested primary sludge is worthy of note.—Ed.)

What Makes the Product Worth the Price?

"Nitrohumus" has been on the market for thirteen years in one form or another, and the pioneering days with it seem to be over. It has qualities for promoting growth which render it highly desirable. In addition to those mentioned by Doctor Rudolfs, it does two additional jobs, one of which may be readily understood—the other being not so clear. (1) It greatly stimulates growth and propagation of angle worms in the soil, such being recognized as highly beneficial in tree culture; (2) it appears to put inorganic fertilizers "to work" in soils in which they otherwise seem sluggish or ineffective. The proof of the latter has been manifested in citrus groves where sewage fertilizer has succeeded admirably, and where inorganic fertilizer previously applied have failed; and (3) it has stimulated growth much more than might be accounted for by the quantity of sludge applied in terms of commercial inorganic fertilizer values.

Dried Screenings

The third material which is produced in this area is the dried fine screenings at the Hyperion sewage disposal plant of the City of Los Angeles. This material, undigested, is dried in a rotary kiln and hauled thence to the orange groves for direct application. One grove in particular which is illustrated in this narrative, has been fertilized with nothing else than these fine screenings. The trees are planted in a sandy, reasonably sterile soil, and an excellent opportunity is offered for comparison with an unfertilized grove directly across the road. The difference between the two is indicative of the highly beneficial character of this type of fertilizer which, upon laboratory analysis would appear to be quite worthless.

Some Demonstrations

The effect of digested sludge upon lawn development is extraordinary. One of the tricks in advertising in this area is to request the prospective customer to let the salesman sprinkle a little of the fertilizer on the front lawn. The agent then writes the name of the fertilizer on the grass in fertilizer; asks the prospective customer to water the lawn a couple of times, with the result that in a week or ten days the name of the sludge is written in bright green across the yard. This very effective method of demonstrating the fertilier's ability has made many sales to a large number of permanent customers.

Commercial growers of iris, dahlias, gladiolas, pansies and marigold, are among a long list of repeat customers using digested sewage sludge for fertilizer. Dairy manure in this area is now selling for $1.50 per ton, delivered, roadside. This is the commercial variety containing about 1¼ per cent nitrogen. Digested sewage sludge, roadside delivery, is selling for $7 per ton. The difference in selling price is not indicative of high pressure salesmanship; to the contrary—it portrays better than any other factor the difference in value and is excellent proof of the fertility value of the product.

MAKING PIPE BUSHINGS FROM STANDARD PIPE

A Handy Kink

DO YOU know that first class pipe bushings can be made out of standard pipe? Many users of pipe don't know that it can be done. Or, if they know that it can be done they don't know the correct size of drill to use for tapping. I have occasionally made bushings out of pipe, but each time I found it necessary to first look into my handbook for the drill size to use and that is so much trouble that it is frequently easier to go to the store and buy a new bushing. Recently, though, I collected all of the data together for all bushings that can be made out of ordinary sizes of extra heavy and double extra heavy piping, compiled the figures in tabular form, and here they are.

For example, to bush from ¼″ to ⅛″ get a piece of ¼″ extra heavy pipe sufficiently long for cutting the outside thread. Then cut the end off to the desired length, drill or ream with a 21/64″ drill (diameter of drill 0.328″) and then tap with a ⅛″ pipe tap. That's all there is to it.

This accompanying table tells the complete story for all ordinary sizes: Note that in one case, ⅜″ to ¼″, the internal diameter of ⅜″ extra heavy pipe is such that no drilling is necessary.

Note also that in bushing from ½″ to ⅜″ either extra heavy or double extra heavy piping can be used.

To Bush From	Use This Size Pipe	Use This Size Drill or Reamer
¼″ to ⅛″	¼″ X	21/64″ drill = 0.328″
⅜″ to ¼″	⅜″ X	None.
½″ to ⅛″	½″ XX	21/64″ drill = 0.328″
½″ to ¼″	½″ XX	27/64″ drill = 0.422″
½″ to ⅜″	½″ XX	9/16″ drill = 0.562″
½″ to ⅜″	½″ X	9/16″ drill = 0.562″
¾″ to ⅜″	¾″ XX	9/16″ drill = 0.562″
¾″ to ½″	¾″ XX	11/16″ drill = 0.688″
1 ″ to ¾″	1 ″ XX	29/32″ drill = 0.907″
1¼″ to 1 ″	1¼″ XX	1/18″ drill = 1.125″
1½″ to 1 ″	1½″ XX	1/18″ drill = 1.125″
1½″ to 1¼″	1½″ XX	1-15/32″ drill = 1.468″
2 ″ to 1½″	2 ″ XX	1-23/32″ drill = 1.72 ″
2½″ to 2 ″	2½″ XX	2- 3/16″ drill = 2.187″
3 ″ to 2½″	3 ″ XX	2- 9/16″ drill = 2.562″
3½″ to 3 ″	3½″ XX	3- 3/16″ drill = 3.187″
4 ″ to 3½″	4 ″ XX	3-11/16″ drill = 3.688″
4½″ to 4 ″	4½″ XX	4- 3/16″ drill = 4.187″
	X = extra heavy pipe. XX = double extra heavy pipe.	

ENGINEERING DATA

CONVERSION FACTORS FOR ENGINEERS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc.. respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.13	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

CHART FOR CONVERTING GRAINS PER GALLON TO POUNDS PER MILLION AND THE REVERSE

Courtesy W. Donaldson and Fuller & McClintock, Engineers

POUNDS OF CHEMICAL REQUIRED PER HOUR FOR VARIOUS PUMPAGES & DOSES

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS 24 HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5*	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.0	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.66	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Exact Values

† COURTESY FULLER & McCLINTOCK ENGINEERS

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " = 100 " " " " = 4.17 " " " " " "

Example: What weight of Chemical must be fed each hour to give a 70 lb dose for a pumpage of 8 O M.G.D. Opposite 8.0 M.G.D and under 70 find 23.3, which is the correct weight.

Note: It is now becoming modern practice to record and report all chemical dosages in pounds per million (P.M.G.) and thereby have simplification in reporting and recording, rather than using the older scheme involving grains per gallon, parts per million, etc.

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe in Inches	SIZE OF TAPS IN INCHES																							
	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	9	63.62	475.9	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9-6	70.88	530.2	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	10	78.54	587.5	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10-6	86.59	647.7	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	11	95.03	710.9	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11-6	103.9	777.0	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2 59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8 22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13 42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19.05	97	42.01	150	64.97	203	87.93	256	110.89	900	389.86
45	19.49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

Theoretical Horsepower

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

Gallons per minute — Ft.	HEAD IN FEET 10	15	20	25	30	35	40	45	50	60	75	90	100
10	03	04	05	06	08	09	10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	'47	.57	.68
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	63	.76	.88	1 01	1.14	1.26	1 51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1 14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1.77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2.52	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6 31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5 56	6.26	6.94	8.33	10.42	12.50	13.89
600	1.52	2.28	3.03	3.79	4.55	5.30	6 06	6.82	7.58	9.09	11.36	13.64	15.15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2.66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10.60	13.26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11.36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10 10	12.12	15.15	18.18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12.87	16.10	19.32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6 31	7.58	8.84	10.10	11.36	12.63	15 15	18.94	22.73	25.25
2000	5.05	7.57	10 10	12.63	15.15	17.67	20.20	22.72	25.25	30.30	37.87	45.45	50.50
3000	7.57	11.37	15.15	18.94	22.72	26.51	30.30	34.09	37.88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25.25	30.30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{3960 \text{ x Effy. of the pump}}$$

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	No. N Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....

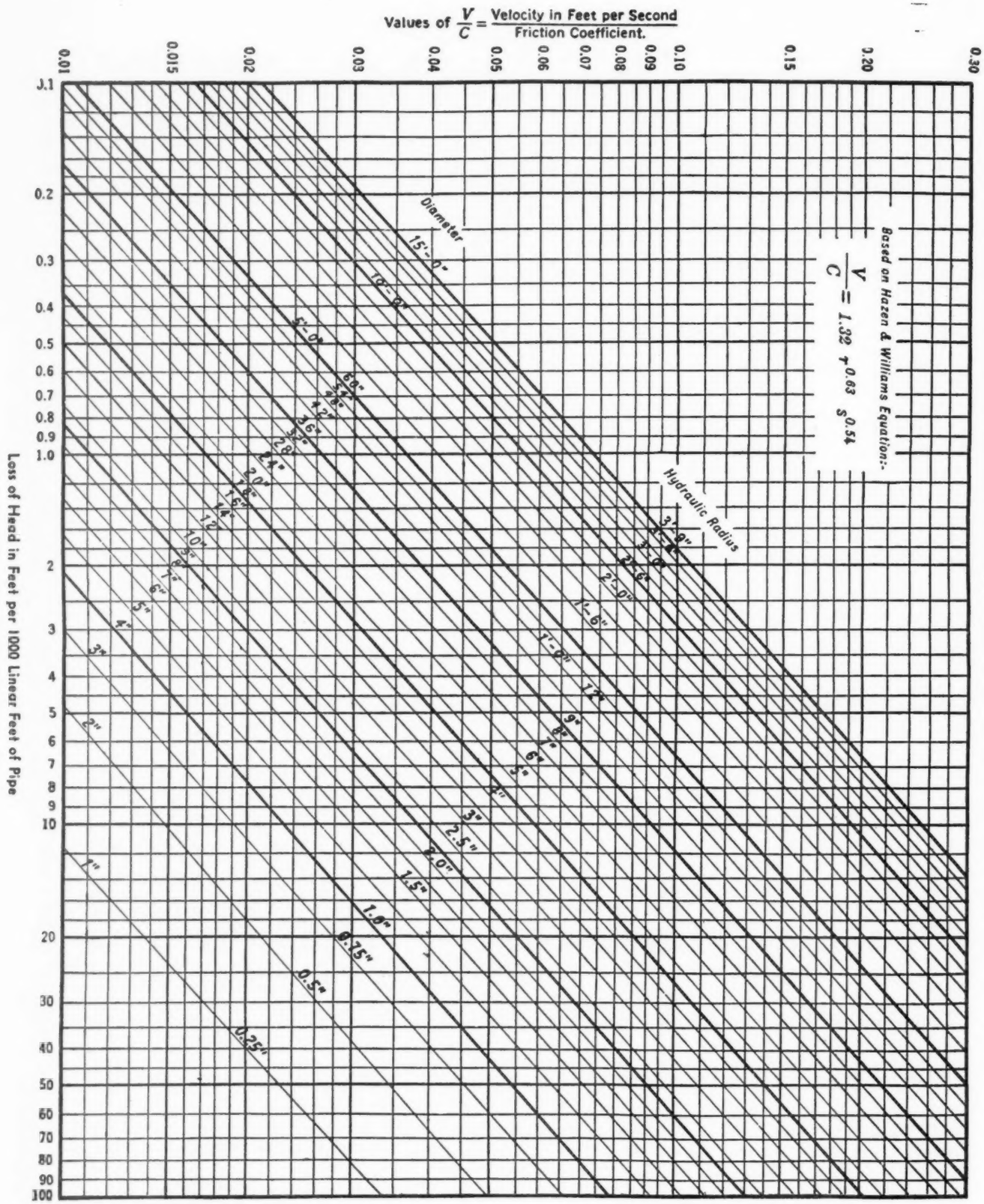


CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE

From "Hydro-Electric Handbook"—John Wiley & Sons

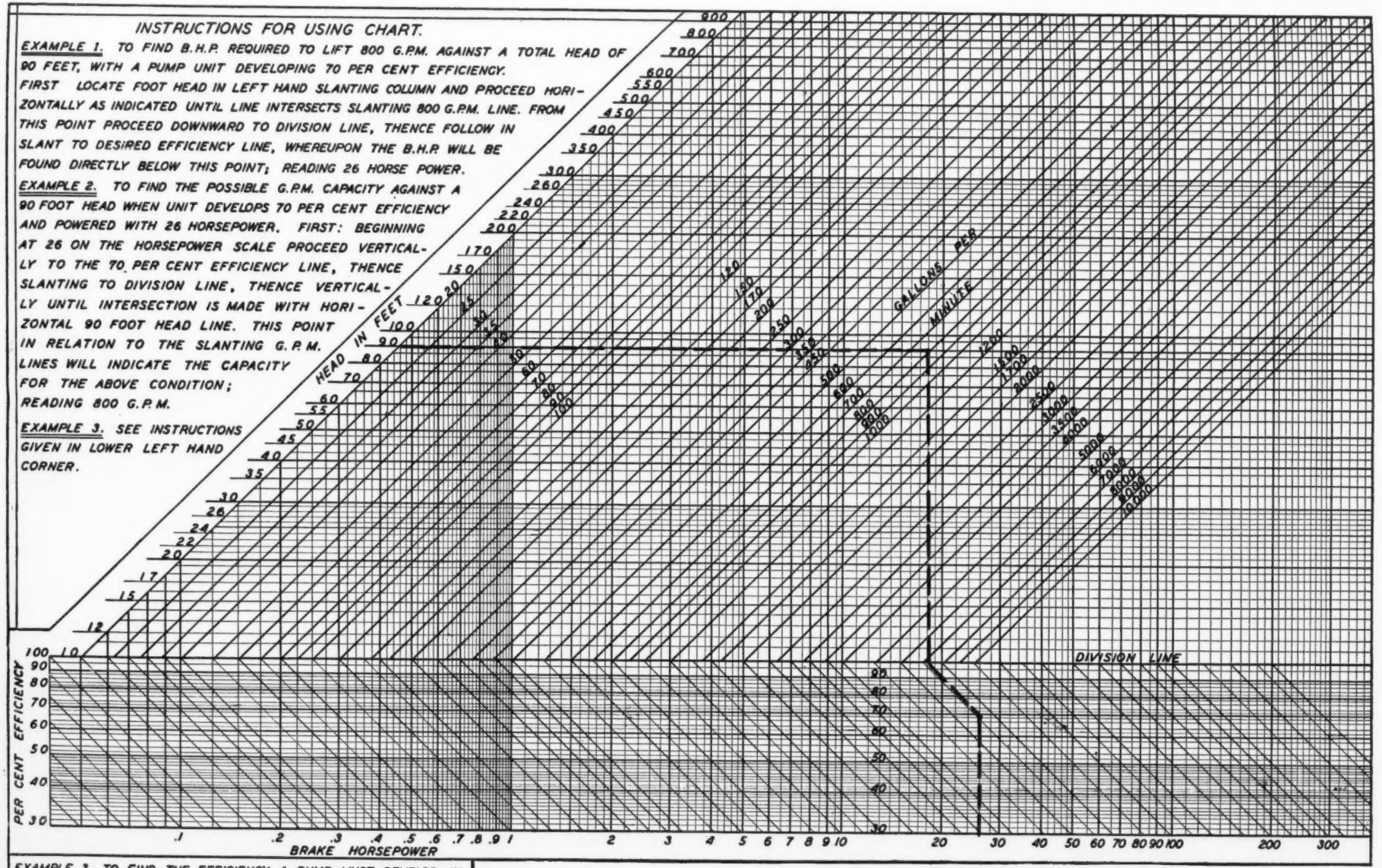

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

DELIVERY CAPACITY AND PRESSURE DROP THROUGH BRASS AND COPPER PIPE

This chart reveals the correct size of brass pipe or copper pipe or tubing to install for desired delivery of flow and residual pressure requirements.

Since the chart has been developed from reliable formulae, developed at Harvard University for straight runs of brass and copper pipes, it is necessary to allow something additional in the way of friction through valves, elbows and fittings. On this account, for the average service line it is good practice to add 20% to the actual length of run of pipe to compensate for loss of head through valves and fittings.

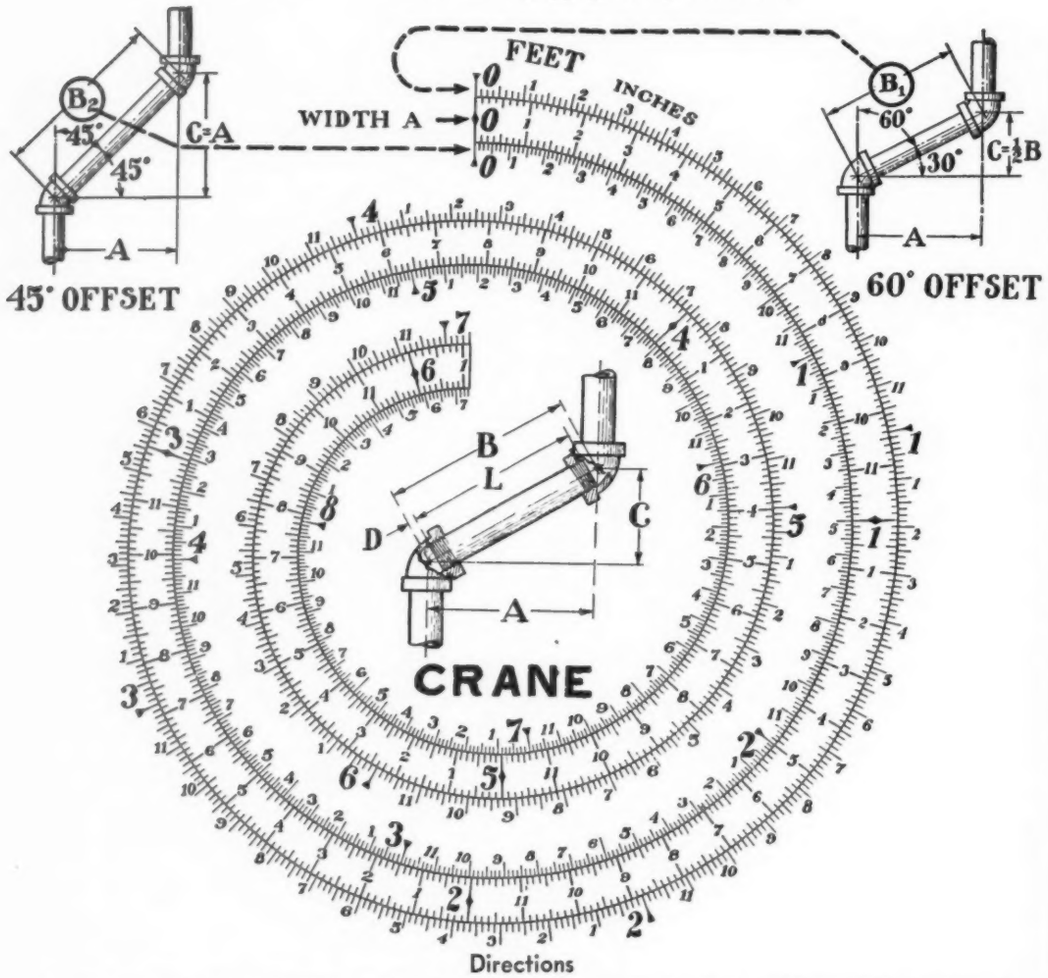
Example: There is an available pressure drop of 30 lbs., and the minimum delivery requirement at fixtures is 35 gals./ min. What size of pipe is required for this service?

Assume a run of 100 ft. to compensate for fittings, etc., add the 20% to secure an "indicated" run of 120 ft. From the 120 ft. point on the base line run up to intersect the down slanting line representing 1 in. pipe; then to the right to the 30 lb. up slanting pressure line; then up to the G.P.M. line. The answer is 36 gals./min. If the ¾ in. size had been tried the result would have been only 17 gals./min. delivery with a 30 lb. pressure available at the main. On the other size an 1¼ in. line will deliver twice the requirement—i. e., 70 gals./min. Or, for the 35 gal. rate of delivery only 10 lbs. of pressure would be required.

It is evident, therefore, that the chart will reveal the proper size of pipe to deliver a required flow with any desired residual pressure at the outlet. In this case use the difference between the normal minimum pressure at the main and the residual pressure desired as the "available" pressure and proceed as in the example given.

OFFSET CHART FOR 45° & 60° SCREWED FITTINGS

(Copyrighted by Crane Co.)



Pipe size...	⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"
45° deduct.	.....	¾"	⅞"	¾"	1"	1⅛"	1⅜"	1⅝"	2"	2"	2⅜"
60° deduct.	.....	.....	.....	1"	1⅛"	1⅜"	1⅝"	2"	2⅜"	2½"	3"
Pipe size...	3½"	4"	4½"	5"	6"	7"	8"	9"	10"	12"	
45° deduct.	2⅝"	3⅛"	3⅜"	3¾"	4⅜"	5¼"	5⅞"	6⅝"	7⅜"	8¾"	
60° deduct.	.....	3⅞"	.....	4⅝"	5⅝"	6⅝"	9⅛"	.....	9⅛"	.....	

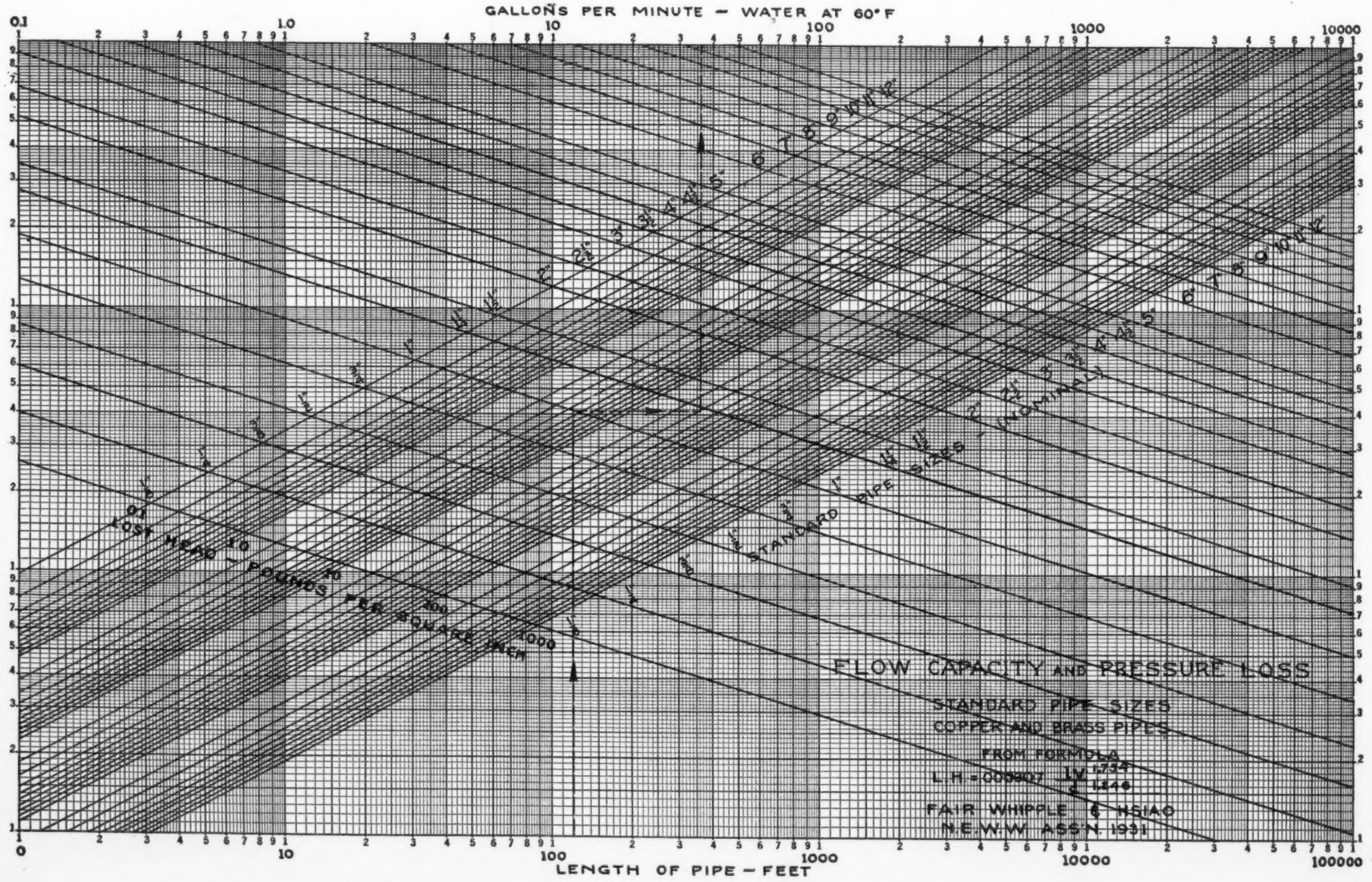
Note—The above figures represent 2xD. To find D divide by 2.

Directions

To determine the actual length of pipe, L, to use for length B, find in the table on right the amount to deduct for the desired pipe size and subtract it from length B.

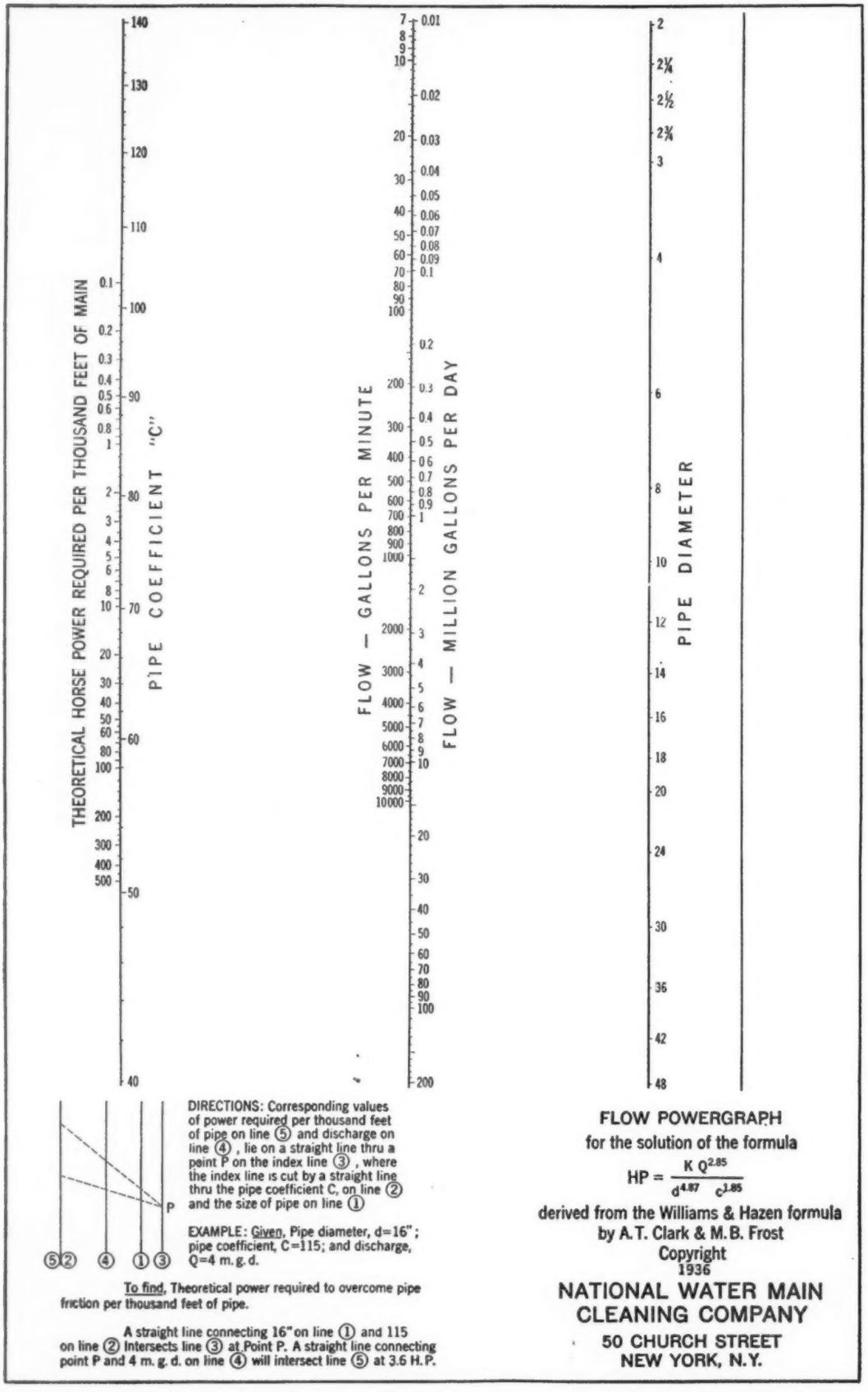
For example, using the above chart, a 45° offset of width 4′-2⅛″ (A) gives the length of run B as 5′-10⅞″ center to center. If it is a 2″ pipe then the table indicates the amount to deduct is 2″. Subtracting this from 5′-10⅞″ gives 5′-8⅞″ as the length of pipe to cut (L).

DELIVERY CAPACITY AND PRESSURE DROP THROUGH BRASS AND COPPER PIPE



A chart developed by the Brass and Copper Research Association from formulae established at Harvard University

Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m.g.d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
$HP = \frac{K\,Q^{2.85}}{d^{4.87}\ C^{1.85}}$
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

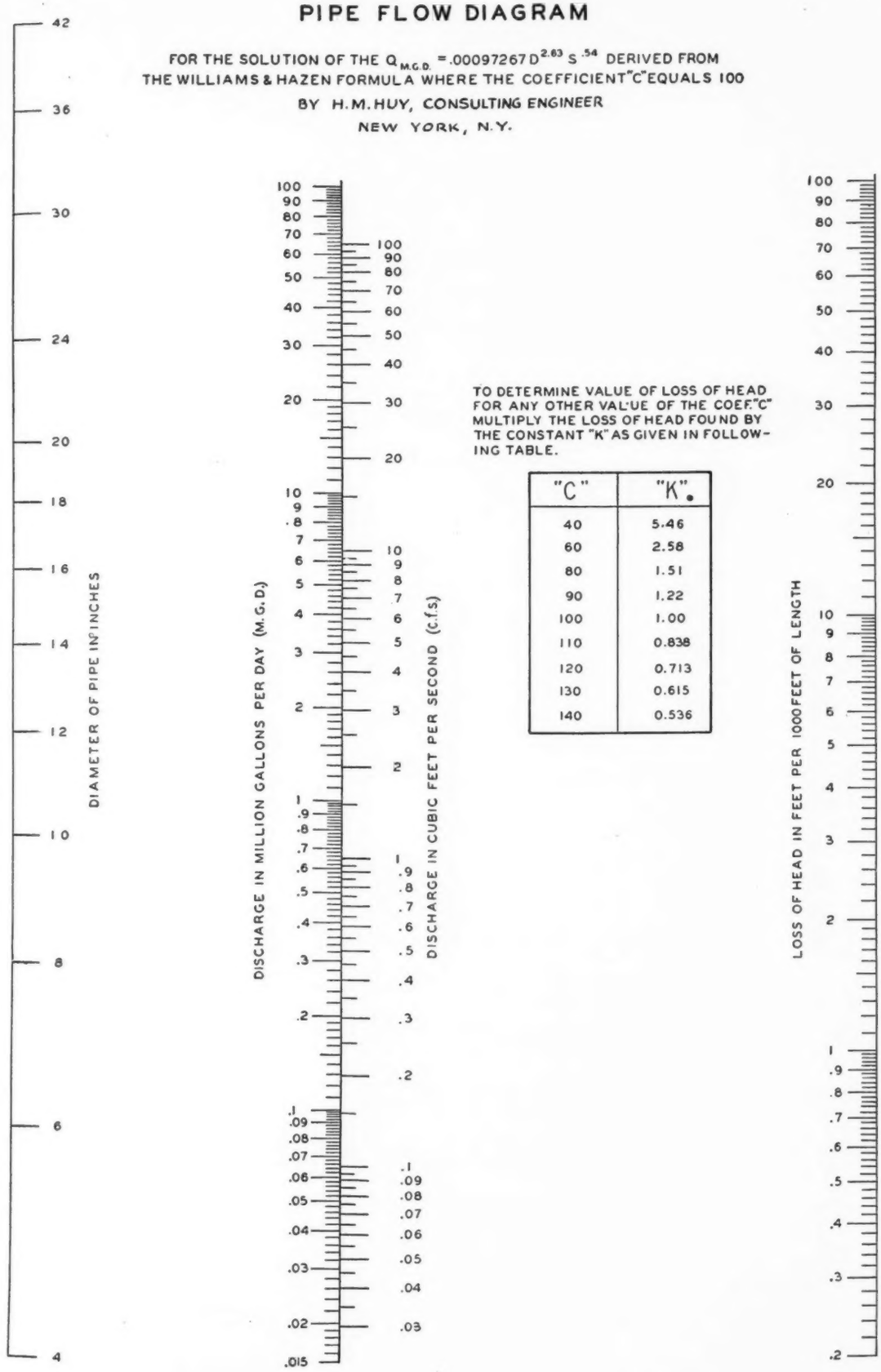
This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267\,D^{2.63}\,S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H.M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.


DIAMETER OF PIPE IN INCHES
DISCHARGE IN MILLION GALLONS PER DAY (M.G.D.)
DISCHARGE IN CUBIC FEET PER SECOND (C.f.s)
LOSS OF HEAD IN FEET PER 1000 FEET OF LENGTH

TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

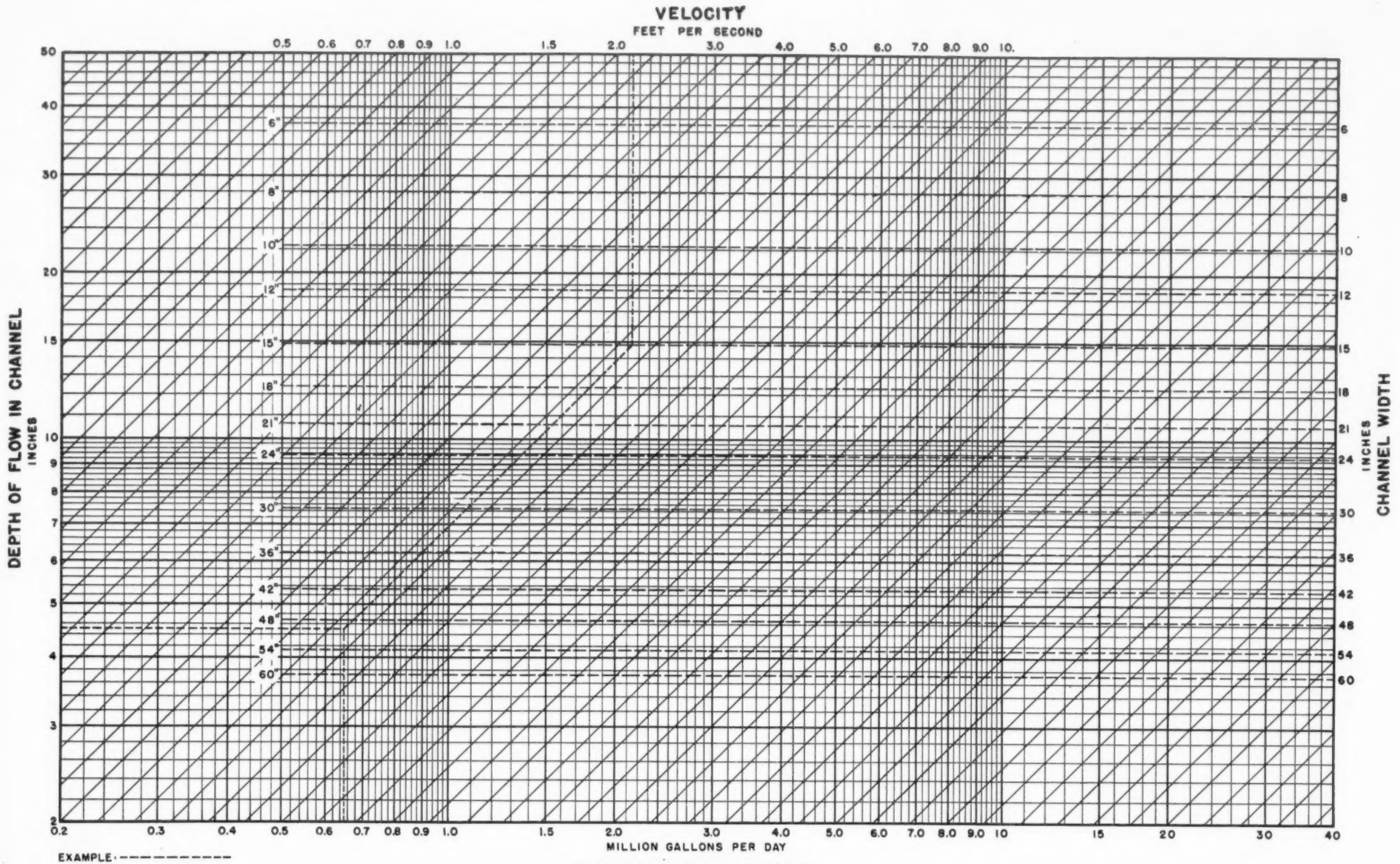
"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

(b) FRICTION COEFFICIENT "C": Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

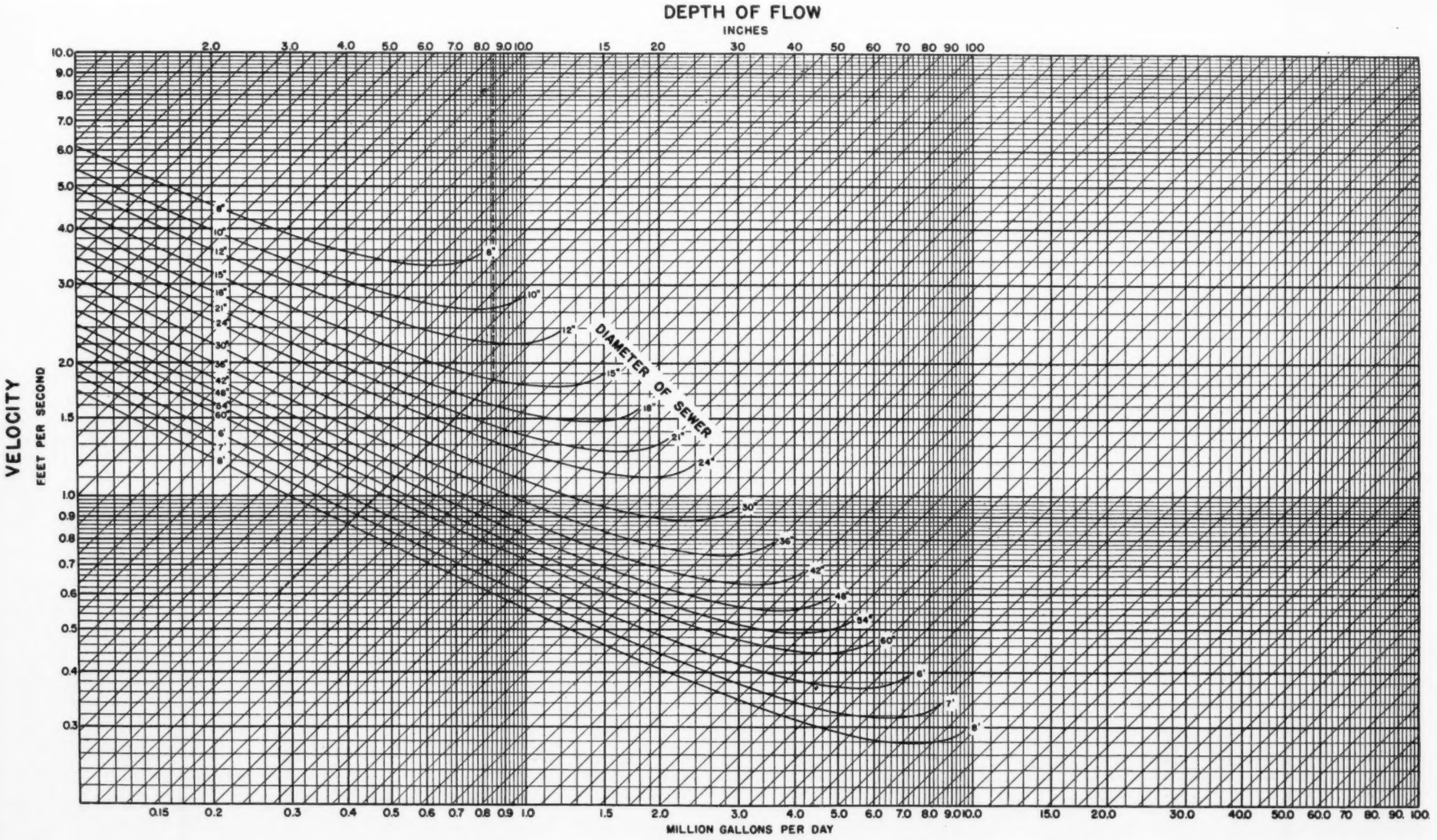
Directions for Application of This Diagram

(a) FRICTION-HEAD LOSS: A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient, due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"], multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.)


VELOCITY
FEET PER SECOND
0.5 0.6 0.7 0.8 0.9 1.0 1.5 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.
DEPTH OF FLOW IN CHANNEL
INCHES
50 40 30 20 15 10 9 8 7 6 5 4 3 2
6" 8" 10" 12" 15" 18" 21" 24" 30" 36" 42" 48" 54" 60"
CHANNEL WIDTH
INCHES
6 8 10 12 15 18 21 24 30 36 42 48 54 60
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.5 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10 15 20 30 40
MILLION GALLONS PER DAY
EXAMPLE
FLOW - 0.65 M.G.D.
DEPTH FLOW - 4½ INCHES.
CHANNEL - 15 INCHES.
VELOCITY = 2.15 F.P.S.
RATE OF FLOW IN CHANNEL
RECTANGULAR CHANNEL

This very useful graph for use in design or in determining rates of flow or velocities in existing rectangular channels is reproduced through courtesy of Chicago Pump Co.



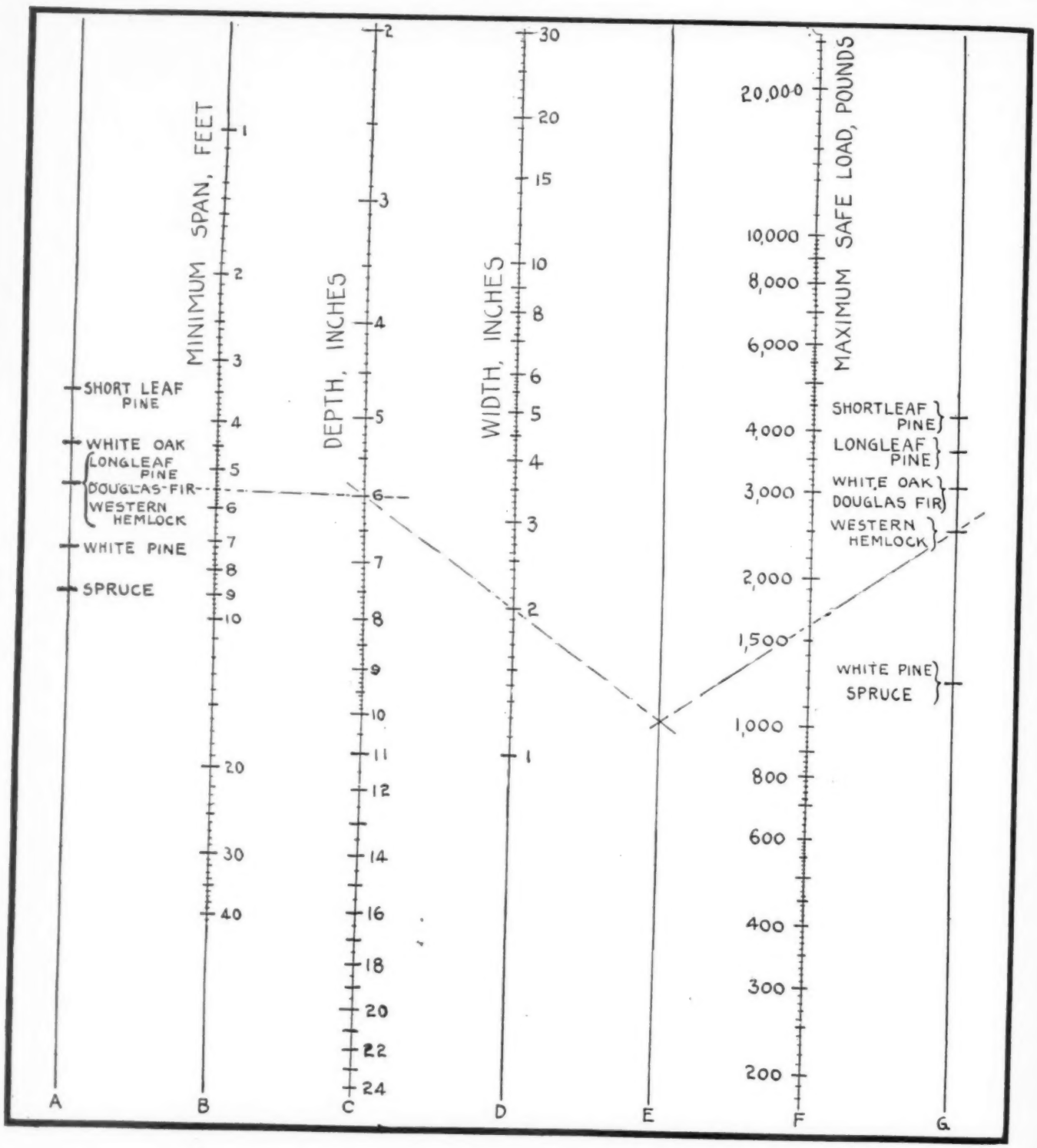
EXAMPLE ----------
DEPTH OF FLOW —— 8¼"
DIAMETER OF SEWER — 15"
FLOW ———— 0.28 M.G.D.
VELOCITY ———— 0.60 F.P.S.

CIRCULAR SEWERS

This very useful graph for use in design or in determining velocities or rates of flow in existing pipe lines and sewers is reproduced through courtesy of Chicago Pump Co.

SAFE LOADINGS FOR WOODEN BEAMS

Contributed by W. F. Schaphorst, M.E.



THE above chart will be found handy for many purposes—in the selection of safe beams made of ordinary woods such as shortleaf white pine, white oak, longleaf pine, Douglas fir, western hemlock, white pine, and spruce. The chart is based on data adopted by the American Railway Engineering Association for safe, uniformly loaded wooden beams of rectangular section.

Example: It is desired to hold 200 lb. per foot on a wooden beam of 2 in. by 6 in. western hemlock over a span of 5 ft. Will the beam be safe?

Run a straight line from the point in column A opposite "western hemlock" over to the depth 6 in column C. The intersection with column B shows the minimum span to be 5.5 ft. The beam will therefore be safe as regards span.

Then from the depth 6 in column C run a straight line through

the width 2 in column D and locate the intersection in column F. Then from that point of intersection run a straight line over to the point in column G opposite "western hemlock." The answer is found at the intersection with column F and is 1,600 pounds.

Since it is desired to hold only 5 × 200 or 1000 lb. on the 5 ft. beam, and since the beam will actually hold 1,600 lb., it certainly is amply safe. In fact, the chart shows that a beam made of white pine or spruce would be safe under this load.

Inversely, the chart may be used for finding any unknown factor or factors. If the kind of wood and the span are known, the first straight line through columns A, B and C gives the minimum depth of beam which must be used. If the width of beam is unknown, the line through the columns E, F, G is located next, and lastly the line through columns C, D, E gives the minimum width of beam in column D.

The weight of the beam itself is included in the safe load given in column F, hence the user of the chart need not worry about that factor.

SAFE LOADINGS FOR I-BEAMS

Contributed by W. F. Schaphorst, M.E.

THE accompanying chart reveals how much any ordinary I-Beam will hold under the very *worst* condition, with the load concentrated in the middle of the span as shown by the sketch on the chart. The chart, for the sake of safety, is based on concentrated loading.

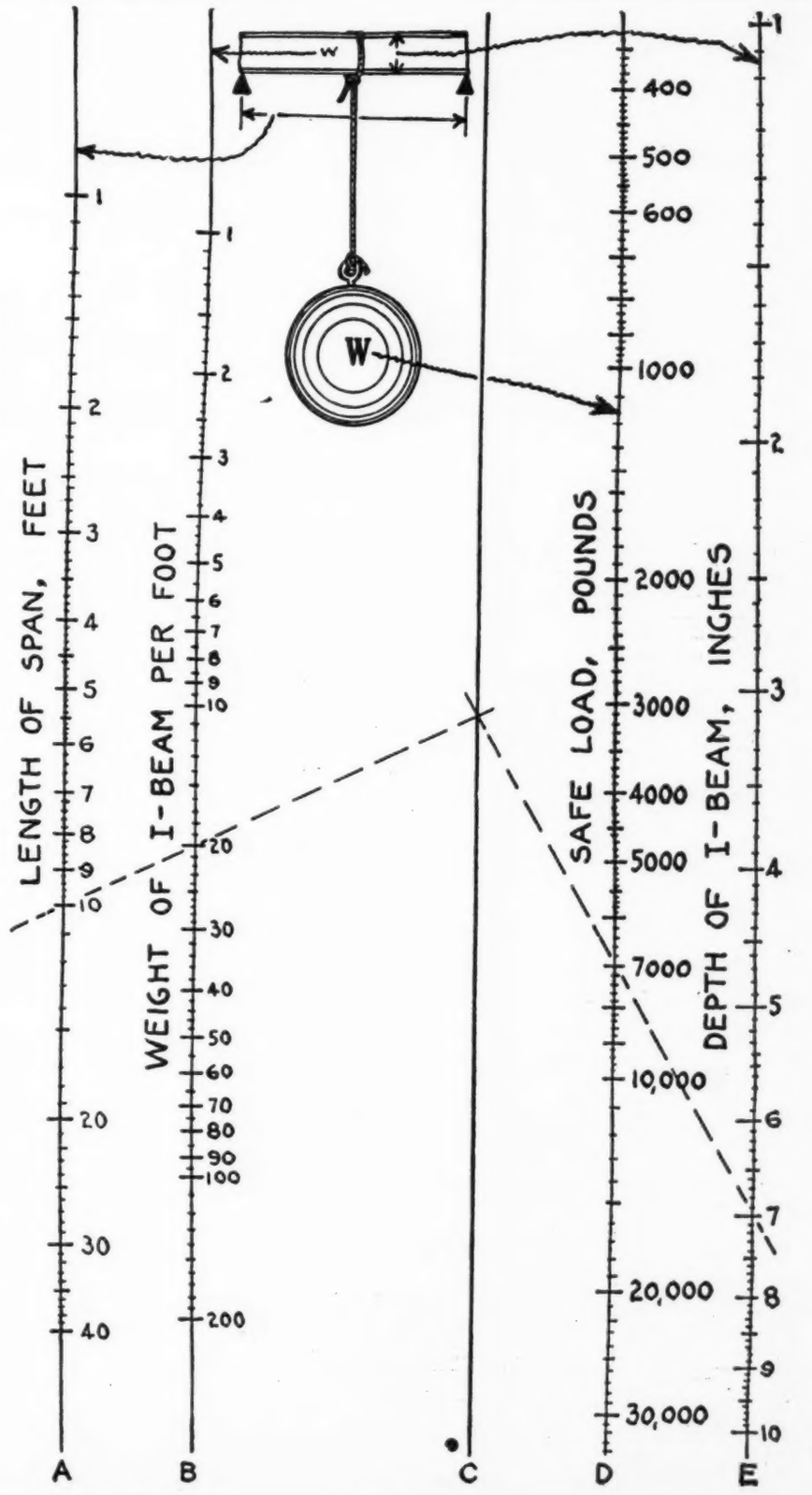
Let us suppose that a weight of 4,000 lbs. must be supported. A 7-inch I-Beam, weighing 240 lbs., is available. It is 12 feet long, and therefore weighs 20 lbs. per foot. The minimum distance between supports that can be obtained for the lifting operation is 10 feet. Is the I-Beam strong enough to lift the 4,000-lb. load?

The Answer

Run a straight line through the 10-ft. (column A) and the 20-lb. (column B) and locate the intersection in column C. Then, from that intersection in column C, run over to the 7-in. (column E). The intersection through column D shows that the I-Beam will support 7,000 lbs. Since the load to be lifted is only 4,000 lbs. the beam is amply strong. In fact, the reader can easily find, by applying the chart, that a 4-inch I-Beam, all other conditions being the same, would safely support the load of 4,000 lbs.

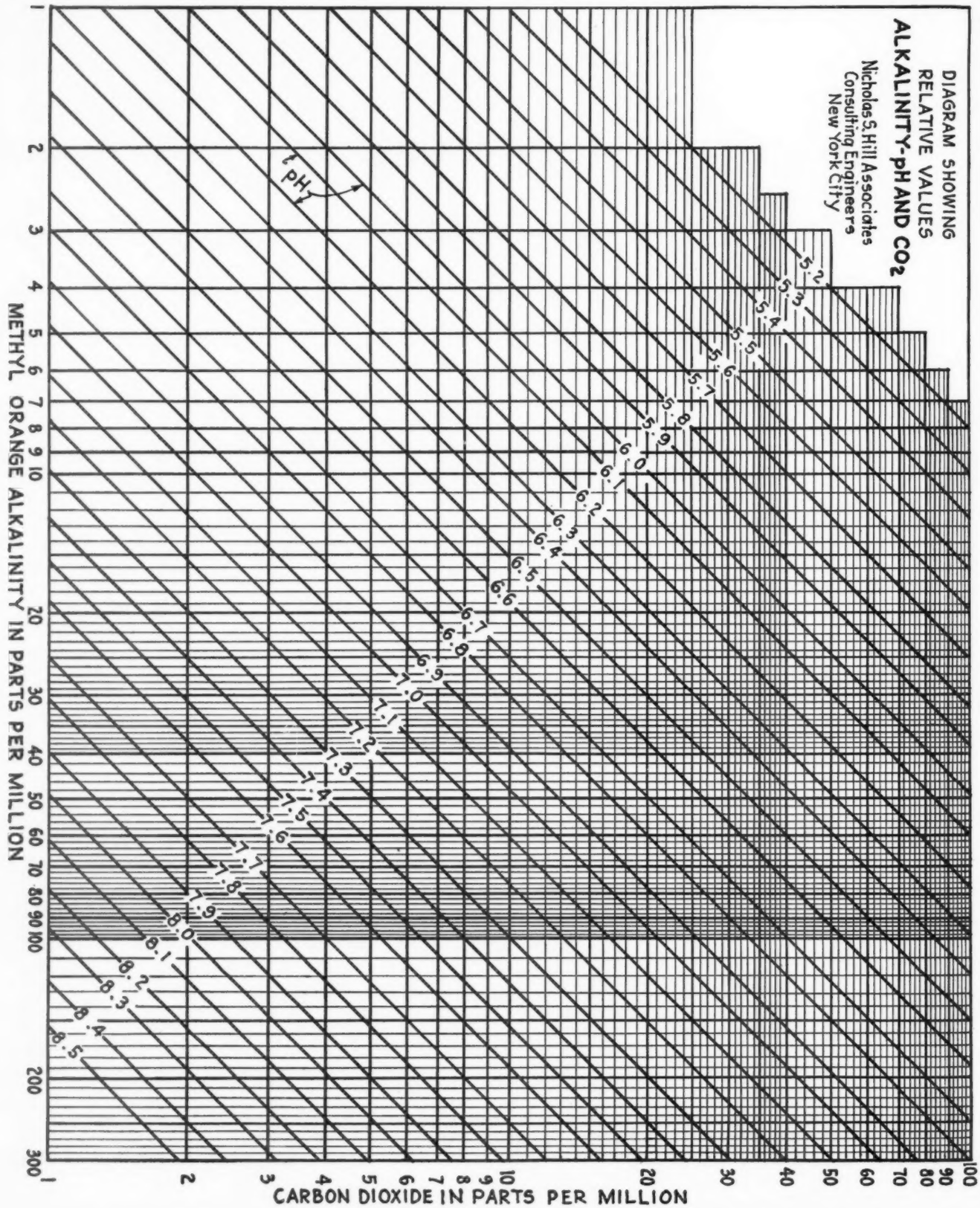
Similarly, it is easy to ascertain the maximum allowable span when the factors in columns B, D and E are known. Or, the necessary weight per foot of I-Beam may be determined when the factors in columns A, D and E are known. Lastly, the depth of beam is determinable when the factors in column A, B and D are known.

For loads that are "uniformly distributed"—not concentrated—the safe loads in column D may be multiplied by two. Thus, the above described beam will support a uniformly distributed load of 14,000 lbs., or 1,400 lbs. per running foot.

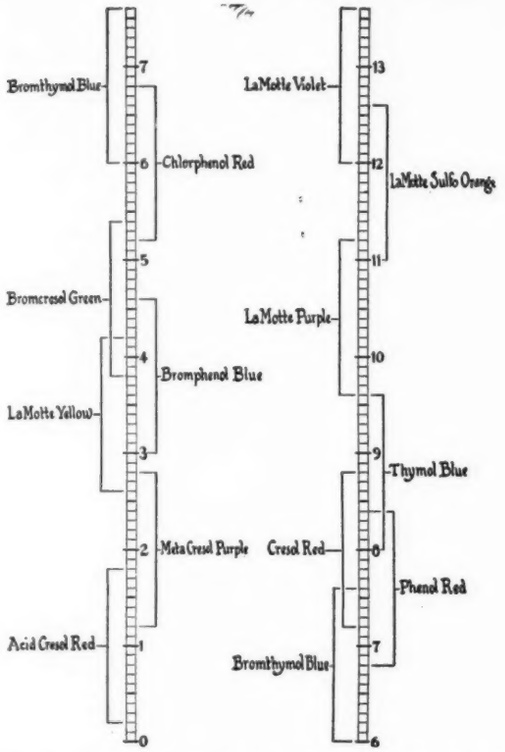


pH CONVERSION CHART

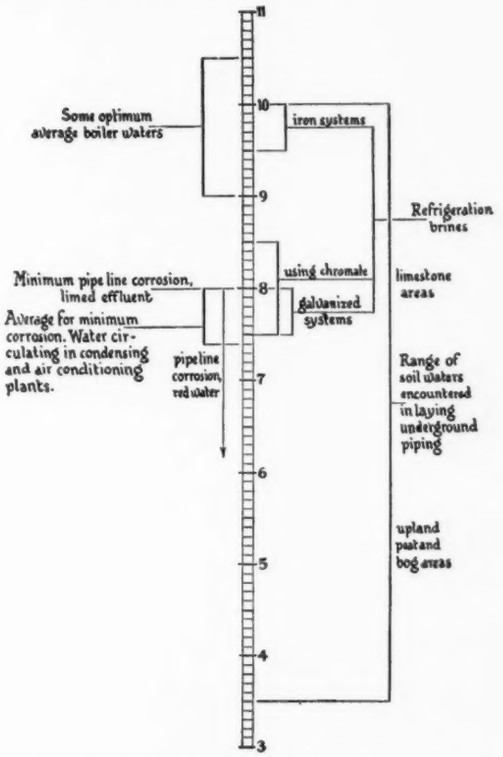
NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. Courtesy Nicholas S. Hill Associates, New York City.*



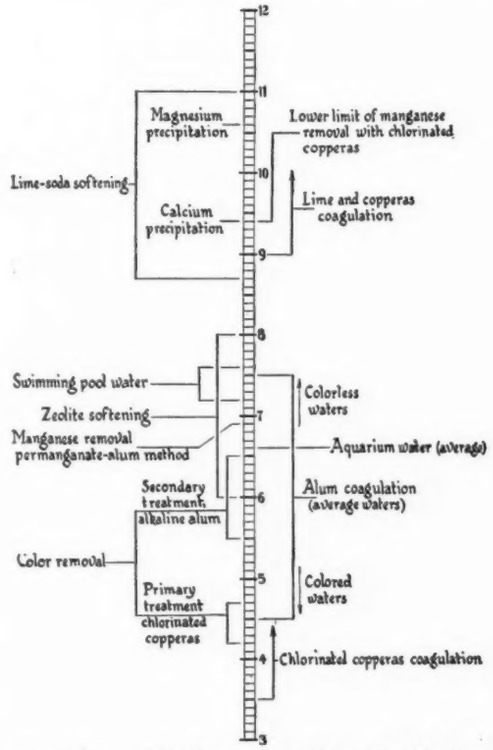
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



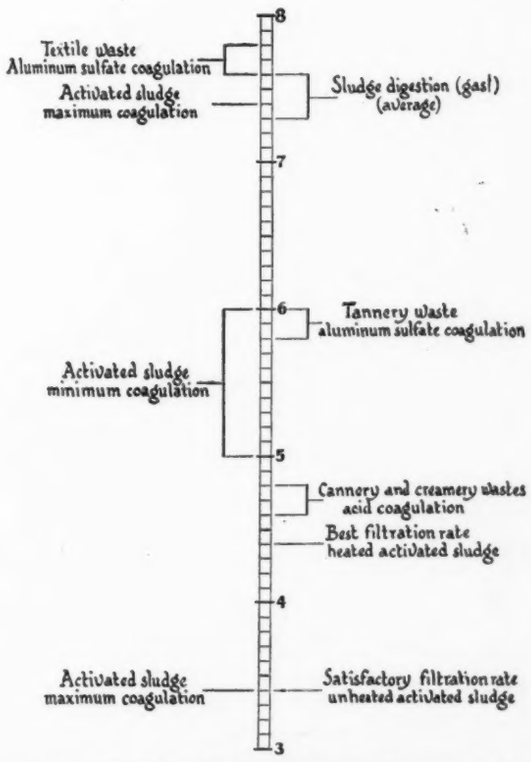
Ranges of Selected Indicators for pH Determination


Some optimum average boiler waters
iron systems
Refrigeration brines
using chromate
limestone areas
galvanized systems
Minimum pipe line corrosion, limed effluent
Average for minimum corrosion. Water circulating in condensing and air conditioning plants.
pipeline corrosion, red water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification

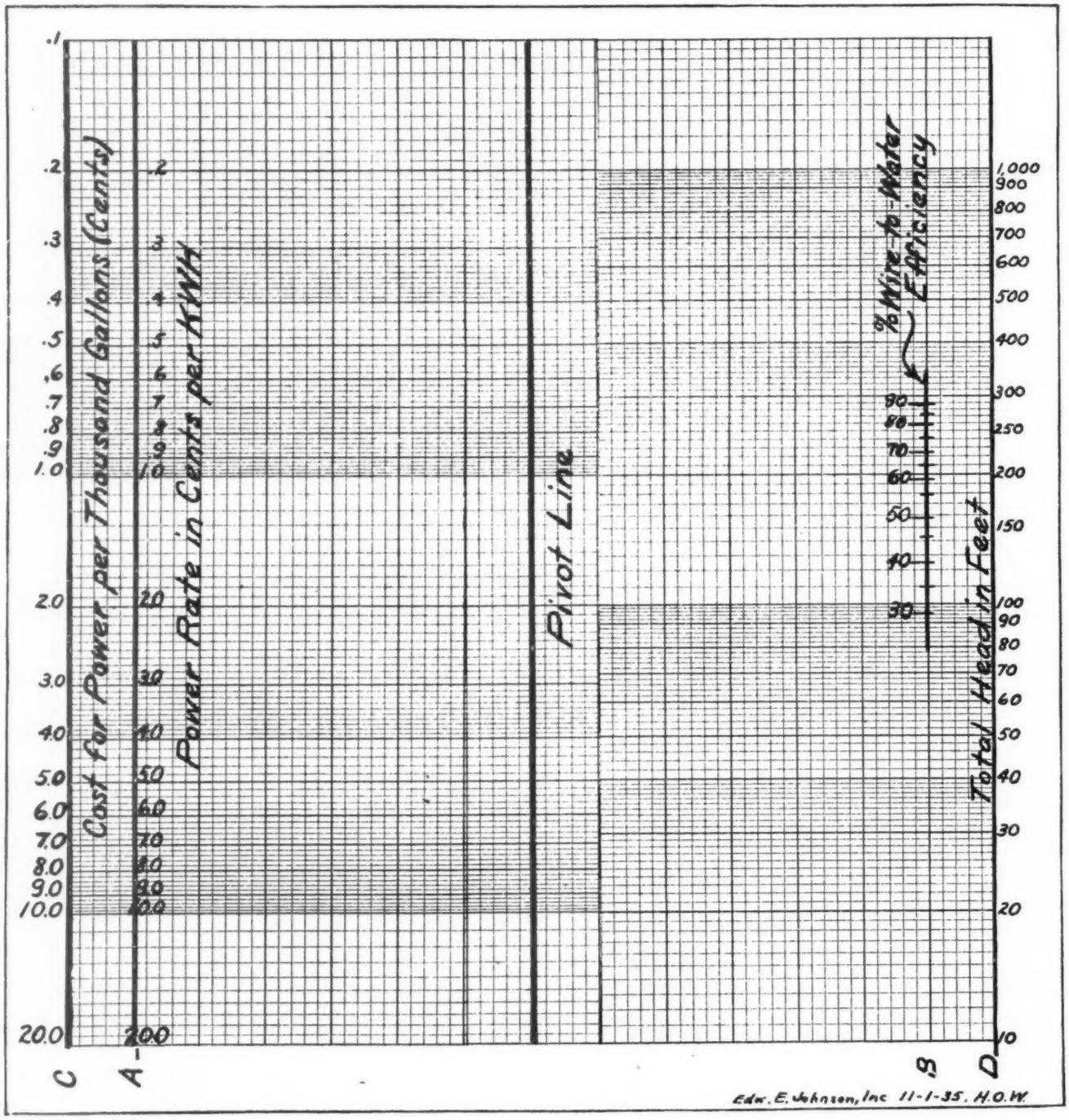

Textile waste
Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (gas!) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes acid coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*



HOW TO COMPARE PUMP EFFICIENCIES*

IF the efficiency of your present pump is 74% and you are planning to install a new pump whose efficiency will be 85%, the improvement will not be merely 11%. There will be an improvement of 13% in efficiency.

It is not uncommon for users and prospective users to subtract the efficiency of the old pump from that of the new one and call the difference the "improvement" in efficiency, but that is not correct. The correct method is to subtract the two efficiencies and then divide the difference by the efficiency of the new pump.

Thus, for example:

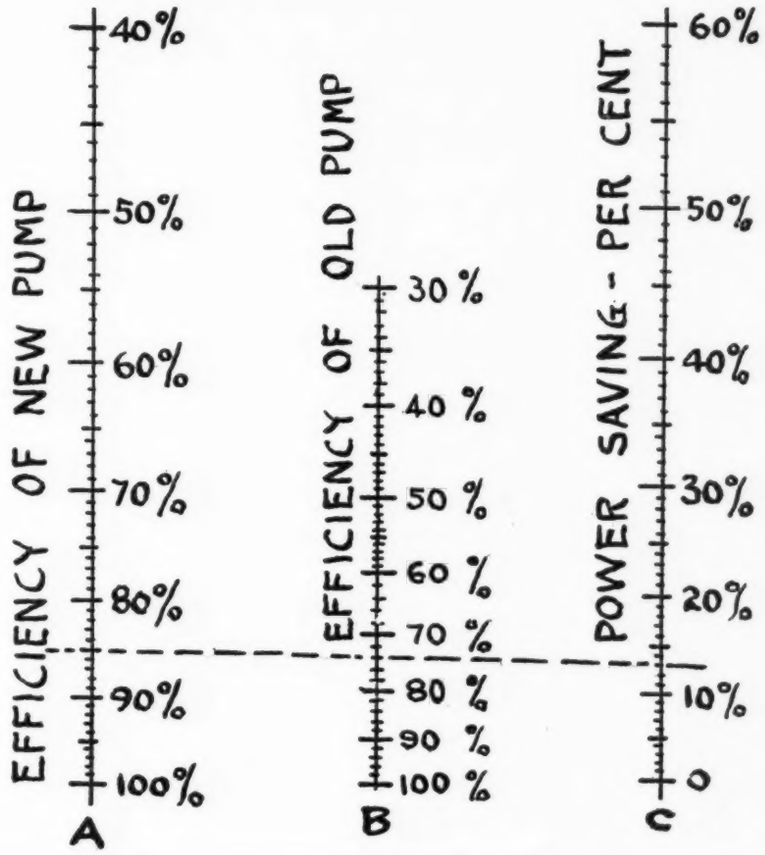
$$0.85 - 0.74 = 0.11$$
$$0.11 \div 0.85 = 0.13$$

which verifies the figures given above.

Let us suppose that you have a pump whose efficiency is only 40% and you are contemplating the installation of one whose efficiency will be 80%. The difference between the two efficiencies is 40%, but that is not the correct improvement. The true improvement is $40\% \div 80\% = 50\%$.

Herewith is a chart that gives the true improvement or "power saving" without any longhand figuring whatever. Simply run a straight line through the efficiency of the new pump, column A, and the efficiency of the old pump, column B, and the power saving or improvement in efficiency is instantly given in column C. Thus the dotted line drawn across this chart shows that where the efficiency of the new pump is 85% and that of the old pump is 74%, the true improvement which can be expected in power saving is 13%.

*Contributed by W. F. Schaphorst, M. E.



HORSE-POWER AND ELECTRICAL DATA

(a) 1 H.P. = 0.746 KW. = 746 watts.

(b) Brake H.P. $= \dfrac{\text{KW. input}}{0.746} \times$ motor efficiency.

(c) Water H.P. $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960}$.

(d) H.P. to lift water $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960 \times \text{pump efficiency.}}$

PRESSURE IN POUNDS PER SQUARE INCH FOR DFFERENT HEADS OF WATER

Head In Feet	0	1	2	3	4	5	6	7	8	9
0	....	.43	.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.50	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.83	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.16	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.49	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.82	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.15	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.48	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.81	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.14	41.57	42.00	42.44	42.87
100	43.30	43.74	44.17	44.60	45.03	45.47	45.90	46.33	46.77	47.20
110	47.63	48.07	48.50	48.93	49.36	49.80	50.23	50.66	51.10	51.53
120	51.96	52.40	52.83	53.26	53.69	54.13	54.56	54.99	55.43	55.86
130	56.29	56.73	57.16	57.59	58.02	58.46	58.89	59.32	59.76	60.20
140	60.62	61.06	61.49	61.92	62.35	62.79	63.22	63.65	64.09	64.52
150	64.95	65.39	65.82	66.25	66.69	67.12	67.55	67.98	68.42	68.85
160	69.28	69.72	70.15	70.58	71.02	71.45	71.88	72.31	72.75	73.18
170	73.61	74.05	74.48	74.91	75.35	75.78	76.21	76.64	77.08	77.51
180	77.94	78.38	78.81	79.24	79.68	80.11	80.54	80.97	81.41	81 81
190	82.27	82.71	83.14	83.57	84.01	84.43	84.87	85.30	85.74	86.17
200	86.60	87.04	87.47	87.90	88.33	88.77	89.20	89.63	90.07	90.50

HYDRAULIC POWER-LIFT CHART*

This chart will be found convenient for solving a multitude of cylinder problems in connection with water plant machinery. It eliminates all of the longhand figuring that is usually necessary in computing the total pressure on a piston, the capacity of a pressure hoist, the pressure needed to achieve a given lift, and so on.

Thus, for instance, if you have a cylinder that is 6 in. in diameter and a pressure of 100 pounds per square inch, the dotted line drawn across this chart connecting the 6 in column A with the 100 in column C shows in column B that the cylinder will have a lifting capacity of a trifle over 2500 pounds. Thus, simply connect the known diameter in column A with the known pressure in column C and the intersection through column B gives the lift capacity in pounds.

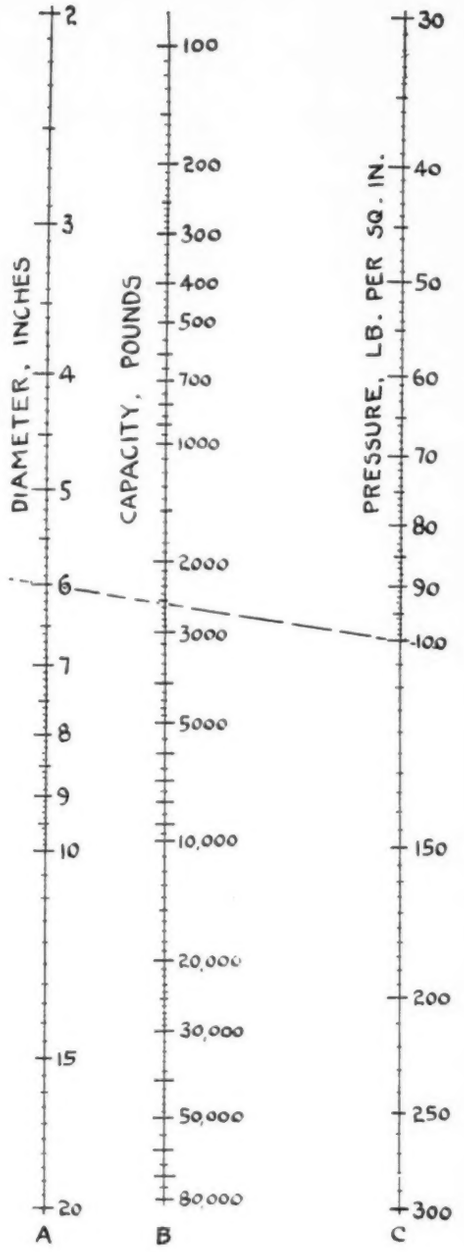
If, on the other hand, it is desired to choose a cylinder to provide a life capacity of 2500 pounds, knowing the pressure to be 100 pounds per square inch, the same dotted line gives a diameter of 6 in. Or, if the available head is only 50 pounds a line from 50 (Col. C) through the 2500 pounds (Col. B) reveals that a piston of 8.5 inches is required.

Run a straight line through any two known factors and the intersection with the third line gives the answer. Thus, if you want a capacity of 2500 pounds and you have a cylinder whose diameter is only 6 in. a pressure of 100 pounds per square inch will be needed to produce the desired capacity. If you have an 8-in. cylinder then the pressure need be but 55 pounds—line from 8 in Col. A through 2500 in Col. B.

As will be noted, the chart has a great enough range to take care of any ordinary requirements, the diameters ranging from 2 to 20 in. and the pressures from 30 to 300 pounds per square inch. The lift capacities (Column B) range all the way from 100 pounds to 80,000 pounds, or 40 tons.

The graph is applicable to all of the fluids that are used in work of this nature—air, water, oil, etc.

*Contributed by W. F. Schaphorst.

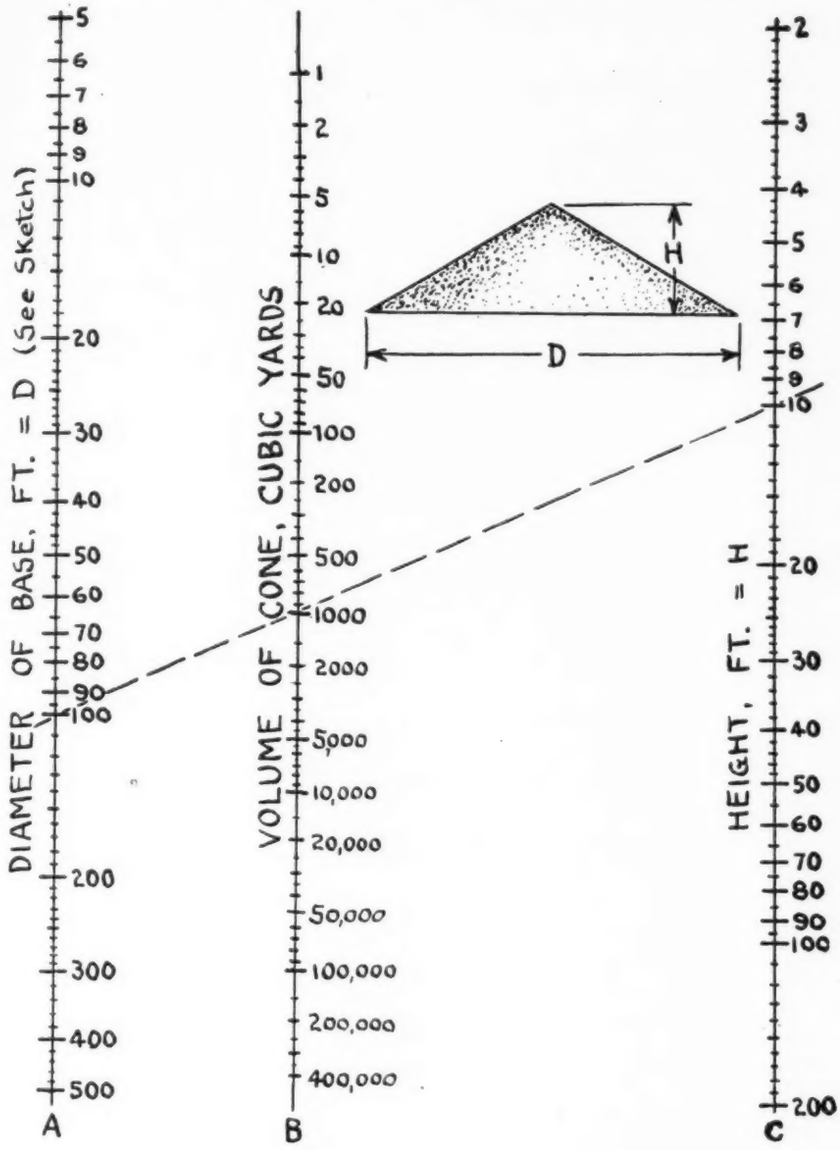


WHERE THE WATER DOLLAR GOES

Here is an interesting and enlightening chart taken from the 22nd Annual Report of the Water Department, Springfield, Ill.

It is based on a survey made by H. V. Pedersen, Water Supt., at Marshalltown, Iowa, to determine what percentage of water in the average consumer's home goes for various uses.

The Springfield folks have taken these percentages and made them more real to the customer, by showing him that out of every dollar paid for water used it only cost him 1 cent to wash his car, only 4 cents for laundry work at home, 3 cents for sprinkling in summer.



CONTENTS OF CONICAL PILES*

Frequently it becomes desirable or necessary to estimate yardage in a pile of dirt, sand, stone, gravel, coal, etc.

Without any figuring whatever the accompanying chart quickly gives the number of cubic yards in any conical pile.

For example, how many cubic yards in a conical pile whose based diameter is 100 ft. and whose height is 10 ft.?

The dotted line drawn across the chart shows how it is done. Run the line through the 100 ft. diameter, column A, and the 10 ft. height, Column C, and the intersection with column B gives the answer as a little less than 1000 cubic yards.

The range of the chart takes care of all diameters from 5 to 500 ft. and all heights from 2 to 200 ft. However, in the event that diameters or heights should be greater or less the same chart is still applicable. Thus if the diameter should be 1000 ft. instead of 100 ft. and if the height should be 100 ft. instead of 10 ft., the same dotted line would solve the problem excepting that the answer would be 1,000,000 cubic yards instead of 1000 cubic yards. In that case the rule is this: For every cipher added to column A, add two ciphers to the answer in column B, and for every cipher added to column C, add one cipher to the answer in column B. This means that when the problem is 1000 ft. diameter and 100 ft. height, three ciphers must be added to the result in column B.

*Contributed by W. F. Schaphorst, M.E.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

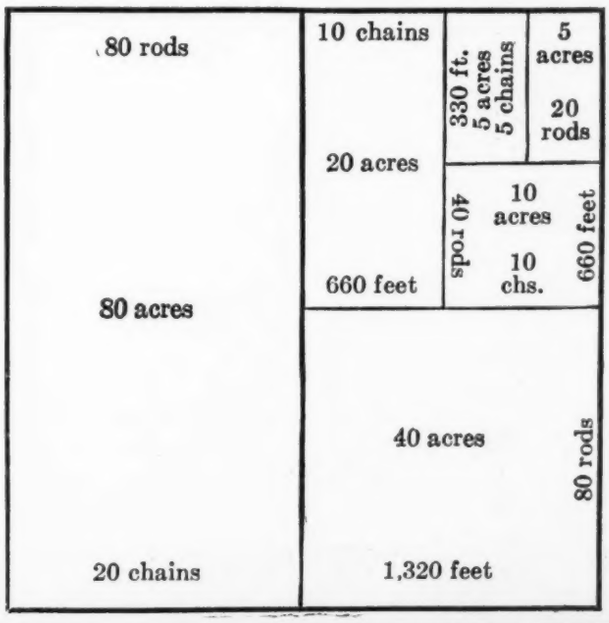
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

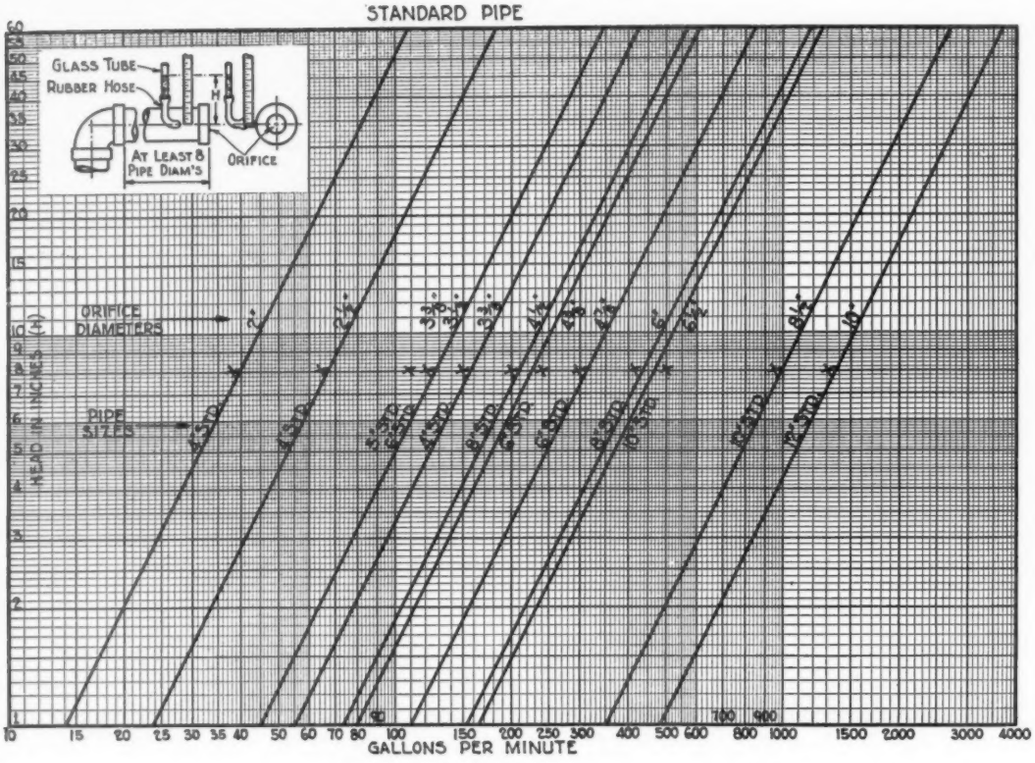
An acre contains 160 square rods.

An acre is about 208¾ feet square.



FLOW MEASUREMENTS WITH THE CIRCULAR ORIFICE AT END OF PIPE

(Peerless Pump Bul.)

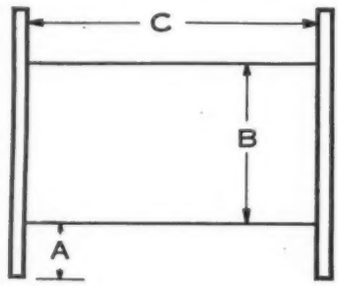


To obtain an accurate result in measuring the flow of water with a circular orifice the following conditions are to be maintained: Pipe must be horizontal with no elbows, obstructions or bends within 8 pipe diameters of discharge end; the orifice must be running full of water and "H" be at least one inch above top of the pipe.

Drill and tap discharge pipe on the side through center line for ⅛" pipe connection one foot back from orifice. It is very important that the ⅛" nipple does not extend inside the inner wall of the pipe and should be absolutely flush.

When the rubber hose connection and the glass tube are installed "H" may be measured from the center of the pipe with an ordinary rule.

See also "Flow Measure by Orifice Method" in Part I.)



FORMULA:— $L = (A + B) \times A \times C \times K$

- L = Length of rope in feet.
- A = Depth of flange in inches. In computing capacity of reels "A" is reduced 1½" to 2" to provide for a clearance.
- B = Diameter of drum in inches.
- C = Width of drum in inches.
- K = Constant which is given below for a given size of rope.

Rope Dia.	Value of "K"	Rope Dia.	Value of "K"
1/32	266.24	7/8	.342
1/16	66.56	1	.262
3/32	29.76	1 1/8	.207
1/8	16.64	1 1/4	.167
5/32	10.76	1 3/8	.138
3/16	7.44	1 1/2	.116
1/4	4.16	1 5/8	.099
5/16	2.67	1 3/4	.085
3/8	1.86	1 7/8	.074
7/16	1.37	2	.066
1/2	1.05	2 1/8	.058
9/16	.828	2 1/4	.052
5/8	.672	2 3/8	.046
3/4	.465	2 1/2	.042

DETERMINING YARDAGE ON REELS OR DRUMS

Although the formula was designed for computing the length of cable, etc., of various diameters, which a reel or drum of given dimensions will accommodate, the method is equally valuable for determining footage remaining on a reel or drum, for inventory purposes or other reasons. In such instances the depth (A) is the depth (in inches) of rope, cable, wire, etc., remaining on the drum or reel.

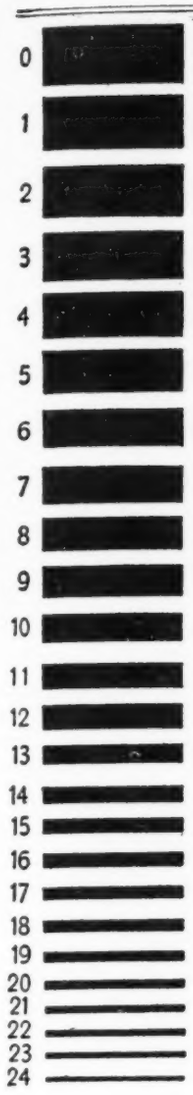
Example: Assume a reel having a 5 in. core (B) and a width of 10 in. (C). The material is ¼ in. in diameter and its depth on the core is 2 in. (A).

$$(B + A) \times A \times C = X$$
$$(5 + 2) \times 2 \times 10 = 140$$

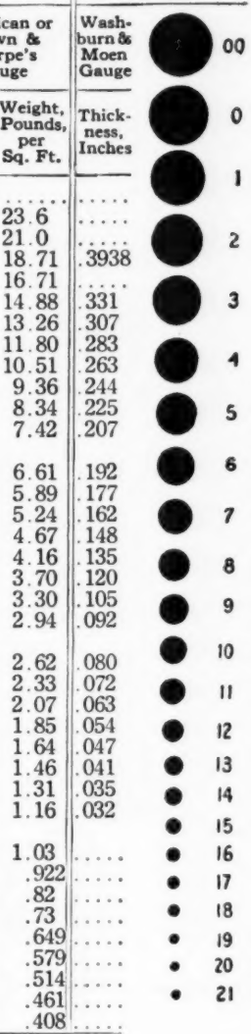
Now refer to table of factors for the "K" value for ¼ in. materials, such being 4.16 ∴ The footage is $140 \times 4.16 = 582$ ft. or, if ½ in. material $140 \times 1.05 = 147$ ft.

If it is desired to determine the length of rope, wire, rubber hose, copper tubing, packing, caulking yarn, etc., wound on a drum or reel, the accompanying formula will prove very helpful.

The sketch, with formula and factors, appeared in Wire Rope Cat. No. 20 of the Hazard Wire Rope Div. of American Chain and Cable Co. Inc.



Number of Gauge	U.S. Standard Gauge Adopted by U. S. Government July 1, 1893		Birmingham or Stubs' Gauge		American or Brown & Sharpe's Gauge		Washburn & Moen Gauge	
	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	
0000000	1/2 .5000	20.4	.....	.....	.....	.....	.....	00
000000	15/32 .46875	19.125	.....	.....	.580	23.6	.....	
00000	7/16 .4375	17.85	.....	.....	.5165	21.0	.....	0
0000	13/32 .40625	16.575	.454	18.5	.46	18.71	.3938	
000	3/8 .375	15.30	.425	17.28	.409	16.71	.....	1
00	11/32 .343	14.025	.38	15.45	.364	14.88	.331	
0	5/16 .312	12.75	.34	13.82	.324	13.26	.307	2
1	9/32 .281	11.475	.30	12.20	.289	11.80	.283	
2	17/64 .265	10.837	.284	11.55	.257	10.51	.263	3
3	1/4 .25	10.2	.259	10.53	.229	9.36	.244	
4	15/64 .234	9.562	.238	9.68	.204	8.34	.225	4
5	7/32 .218	8.925	.22	8.95	.181	7.42	.207	
6	13/64 .203	8.287	.203	8.25	.162	6.61	.192	5
7	3/16 .187	7.65	.18	7.32	.144	5.89	.177	
8	11/64 .171	7.012	.165	6.71	.128	5.24	.162	6
9	5/32 .156	6.375	.148	6.02	.114	4.67	.148	
10	9/64 .140	5.737	.134	5.45	.101	4.16	.135	7
11	1/8 .125	5.1	.12	4.88	.09	3.70	.120	
12	7/64 .109	4.462	.109	4.43	.08	3.30	.105	8
13	3/32 .093	3.825	.095	3.86	.072	2.94	.092	
14	5/64 .078	3.187	.083	3.37	.064	2.62	.080	9
15	9/128 .070	2.868	.072	2.93	.057	2.33	.072	
16	1/16 .062	2.55	.065	2.64	.05	2.07	.063	10
17	9/160 .056	2.295	.058	2.36	.045	1.85	.054	
18	1/20 .05	2.04	.049	1.99	.04	1.64	.047	11
19	7/160 .043	1.785	.042	1.71	.035	1.46	.041	
20	1/30 .037	1.53	.035	1.42	.032	1.31	.035	12
21	11/320 .034	1.402	.032	1.30	.028	1.16	.032	
22	1/32 .031	1.275	.028	1.14	.025	1.03	.....	13
23	9/320 .028	1.147	.025	1.02	.022	.922	.....	
24	1/40 .025	1.02	.022	.895	.020	.82	.....	14
25	7/320 .021	.892	.02	.813	.017	.73	.....	
26	3/160 .018	.765	.018	.732	.015	.649	.....	15
27	11/640 .017	.701	.016	.651	.014	.579	.....	
28	1/64 .015	.637	.014	.569	.012	.514	.....	16
29	9/640 .014	.573	.013	.....	.011	.461	.....	
30	1/80 .012	.51	.012	.....	.01	.408	.....	17



STANDARD GAUGES*

Sheets, Plates and Wire

Sheet mills roll steel sheets to U. S. gauge unless otherwise ordered. Plate mills usually roll heavy plates, 3/16 and heavier, and light plate No. 8 to No. 12, to Birmingham gauge. In figuring weights of steel plates add to above the allowance for overweight, adopted by Association American Steel Manufacturers. All steel shee's in our *stock are rolled to the U. S. Standard Gauge. Brass is rolled to thickness by Brown & Sharpe's American Gauge. Copper is rolled to thickness by Stubs' or Birmingham Gauge.

* From Link-Belt Catalog.

CONTENTS OF HORIZONTAL TANKS AND PIPE

Per Foot of Length, for Various Depths

h = Depth of Liquid Inches	d = Diameter of Tank, Inches									
	12		18		24		30		36	
	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.
2	0.64	0.0860	0.80	0.1072	0.93	0.1244	1.05	0.1400	1.15	0.154
4	1.73	0.2317	2.18	0.2920	2.57	0.3440	2.90	0.3878	3.21	0.429
6	2.94	0.3927	3.85	0.5149	4.59	0.6140	5.23	0.6988	5.80	0.775
8	4.14	0.5537	5.67	0.7578	6.85	0.9152	7.85	1.049	8.75	1.17
10	5.23	0.6994	7.55	1.009	9.26	1.238	10.72	1.432	12.0	1.60
12	5.87	0.7854	9.38	1.252	11.75	1.571	13.72	1.833	15.4	2.03
14	.....	.....	11.04	1.476	14.24	1.903	16.82	2.248	19.0	2.54
16	.....	.....	12.43	1.659	16.65	2.226	19.90	2.660	22.6	3.02
18	.....	.....	13.22	1.767	18.91	2.527	23.00	3.075	26.4	3.53
20	.....	.....	.....	.....	20.93	2.797	26.00	3.476	29.6	3.95
22	.....	.....	.....	.....	22.57	3.017	28.85	3.859	33.4	4.46
24	.....	.....	.....	.....	23.50	3.141o	31.49	4.209	37.4	5.00
26	.....	.....	.....	.....	.....	.....	33.82	4.521	40.4	5.40
28	.....	.....	.....	.....	.....	.....	35.67	4.768	43.7	5.84
30	.....	.....	.....	.....	.....	.....	36.72	4.908	46.6	6.23
32	.....	.....	.....	.....	.....	.....	.....	.....	49.1	6.55
34	.....	.....	.....	.....	.....	.....	.....	.....	51.2	6.85
36	.....	.....	.....	.....	.....	.....	.....	.....	52.9	7.07

(Reprinted with permission from the Piping Handbook, by Walker and Crocker. Published by McGraw-Hill Book Company.)

Formulas for determination of approximate capacity of horizontal cylindrical tanks for any depth. Given:—diameter of tank d and height of segment h.

To find area of segment

when $h = 0$ to $\frac{1}{4}d$; area $= h\sqrt{1.766\,dh - h^3}$

when $h = \frac{1}{4}d$ to $\frac{1}{2}d$; area $= h\sqrt{0.017d^2 + 1.7dh - h^3}$

1 cu. ft. = 7.4805 U. S. gal.

GALLONS IN WATER SUPPLY PIPE*

Water supply men often want to know the volume of a given length of pipe in gallons. This writer does not know of any table that gives such values and where volumes are to be found they are usually given in cubic feet. Besides, the range of a table is seldom great enough to cover all desired conditions.

This chart takes care of all standard pipe sizes from ⅛ inch to 15 inches on scale A, and any length of pipe line from 0.1 foot to 800,000 feet on scale B. Scale C shows volumes from 1 to 1,000 gallons.

In using the chart simply run a straight line through the pipe size (column A) and the length of pipe line (column B) and the intersection with column C immediately gives the total number of gallons in the pipe or pipe line.

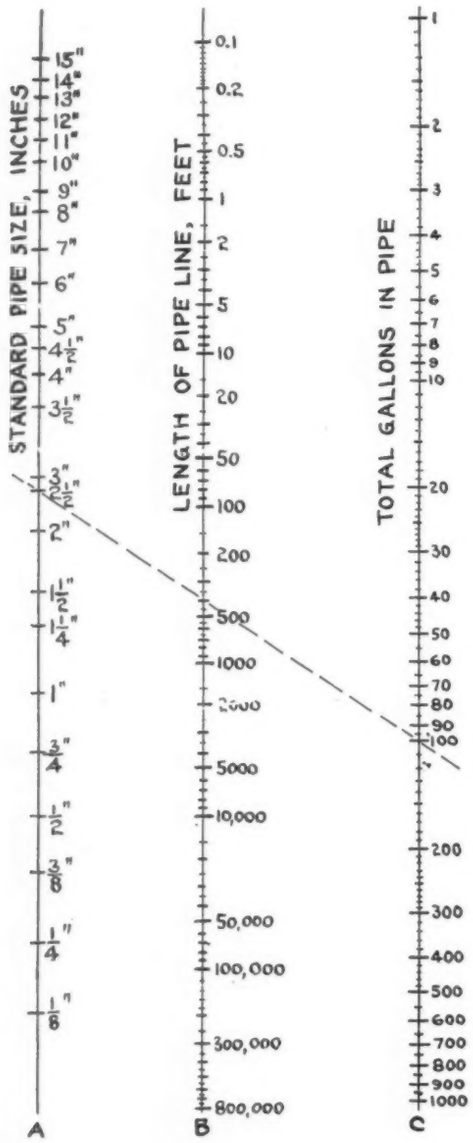
Thus the dotted line drawn across this chart shows that if the pipe size is 2½ inches (column A) and the length of line is 400 feet (column B) the volume of the pipe (column C), is 100 gallons.

For a length of pipe which is found to hold more than 1,000 gals. the volume is readily found for 1/10th or 1/100th of the length and the C scale reading multiplied accordingly.

Or, if it is desired to know the length of pipe line required to hold a given number of gallons, or the size of the pipe necessary to hold a given number of gallons within certain limitations of length, the chart may be conveniently applied. In other words, knowing two factors in any two of the three columns, the unknown in the third column is quickly found.

Here is another "trick": To determine the volume of a ½-inch pipe one foot long, the easiest way is to run a line through the ½-inch, column A, and the 10,000 in column B. The intersection with column C says 160 gallons, but that, of course, is for a pipe line 10,000 ft. long. By merely pointing off four places to the left we have 0.016 gal, as the volume of a ½-inch pipe one foot long.

* Contributed by W. F. Schaphorst (M.E.), Newark, N. J.



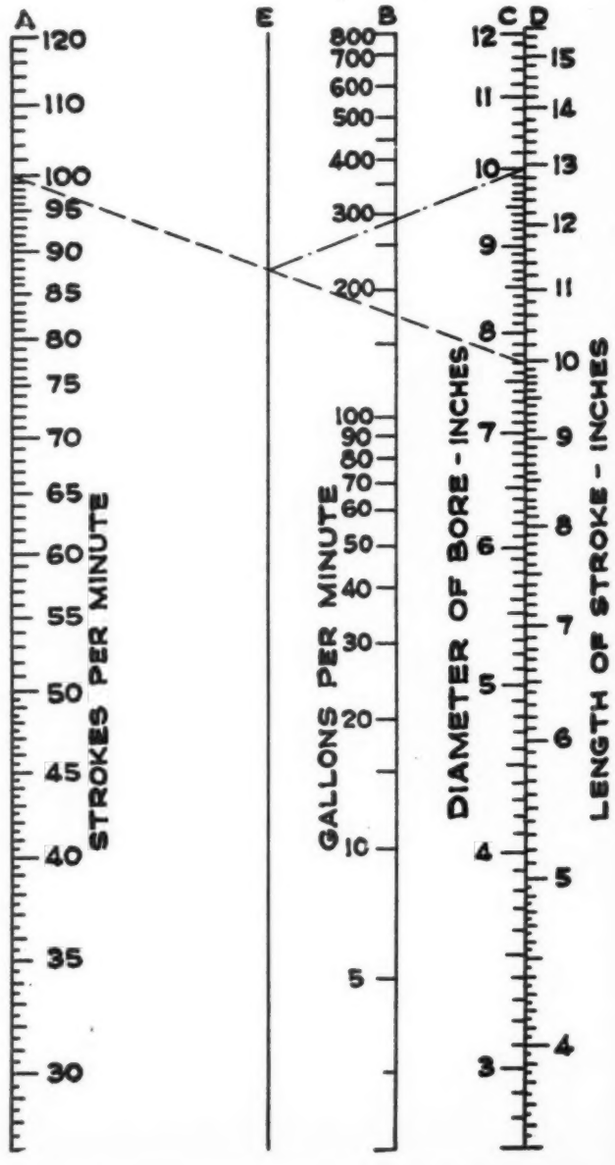
CAPACITY OF RECIPROCATING PUMPS

This nomograph shows the capacity of a reciprocating pump operating without slip where the size and number of strokes is known.

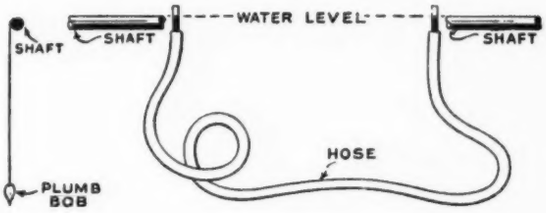
Example:

A pump of 10-in. bore, 10-in. stroke running 100 strokes per minute: Locating 100 on line "A" and 10-in. on line "D" we draw a line between them; then locating the intersection of this line with line "E" and locating 10-in. on line "C" we draw a connecting line. Where this line crosses "B" we have the delivery, or 290 G.P.M., of the reciprocating pump.

(From "Data Handbook" of Economy Pumps, Inc.)



ACCURATE LEVELLING AND ALIGNING BY SIMPLE METHOD



The accompanying sketch shows how to do it. Slip gauge glasses into each end of an ordinary rubber hose and fill with enough water so that the level will show in each glass, as indicated.

When filling the hose with water, care must be exercised to be certain that all air is gotten out of the hose. Hold it in a U-position when filling. Do not attempt to fill it by immersing the hose in a tub of water. Also, one end of the hose must not be warmer than the other end. If the water in one end is warmer it will occupy greater volume and the level will not be true. In other words, get rid of all of the air and use water of the same temperature throughout.

The sketch also shows one of the simplest methods by which shafting can be aligned. Suspend several plumb bobs from the shaft as shown, all from the same side of the shaft. It is then possible to glance along from one end to the other and one can see whether or not the cords supporting the plumb bob are in perfect alignment. If they are not in alignment, the shafting is not straight and should be rectified. A cord stretched lengthwise near the vertical cords enables one to measure the exact amount of misalignment and assist in making the shaft straight.

EXPANSION CHART*

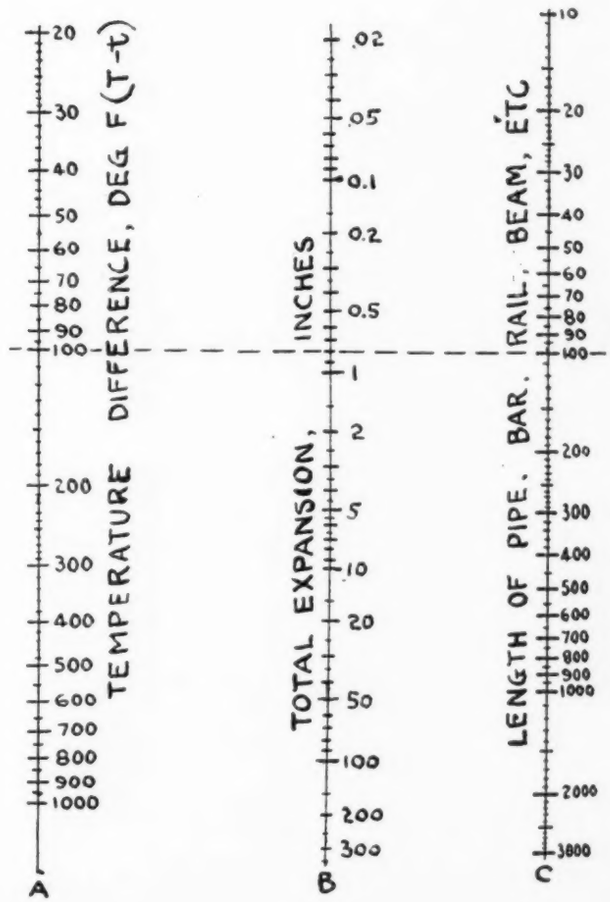
This chart is useful for determining the expansion in piping, rods, tubes, beams, shafts, columns, struts, etc., for any ordinary temperature difference. It makes "longhand figuring" unnecessary. Simply lay a straight-edge across the chart once or stretch a fine black thread across, as indicated by the dotted line, and the problem is solved.

Example: If a certain pipe line 100 ft. long is subjected to a temperature variation of 100 deg. F., what will be the total expansion in inches?

Simply connect the 100 deg. *temperature difference*, column A, with the 100 ft. length, column C. The intersection with column B gives the answer as 0.8 in. That is all there is to it.

The chart can also be used for determining the allowable temperature difference where a definite amount of space is available for expansion and contraction. Thus if the length of the pipe is 100 ft. and the allowable expansion is 0.8 in. the same line would show that a temperature difference of 100 deg. F. would be the limiting amount.

*From an article by W. F. Schaphorst, M.E., Newark, N. J., in WATER WORKS & SEWERAGE, March, 1939.



PROPORTIONING CONCRETE

Proportions of Mixtures			Material For One Cubic Yard Concrete — Gravel ¾" and under			Stone 1" and under, dust screened out			Stone 2½" and under, dust screened out		
Cement	Sand	Stone	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards
1	2	3	1.54	.47	.73	1.70	.52	.77	1.73	.53	.79
1	2	4	1.34	.41	.81	1.46	.44	.89	1.48	.45	.90
1	2	5	1.17	.36	.89	1.27	.39	.97	1.29	.39	.98
1	2½	4	1.24	.47	.75	1.35	.52	.82	1.38	.53	.84
1	2½	5	1.10	.42	.83	1.19	.46	.91	1.21	.46	.92
1	2½	6	.98	.37	.89	1.07	.41	.97	1.07	.41	.98
1	3	5	1.03	.47	.78	1.11	.51	.85	1.14	.52	.87
1	3	6	.92	.42	.84	1.01	.46	.92	1.02	.47	.93
1	3	7	.84	.38	.89	.91	.42	.97	.92	.42	.98
1	4	6	.83	.51	.77	.90	.55	.82	.92	.56	.84
1	4	7	.77	.47	.81	.83	.51	.89	.84	.51	.90
1	4	8	.71	.43	.86	.77	.47	.93	.78	.48	.95
1	4	9	.65	.40	.89	.71	.43	.97	.73	.46	1.01

1 Bag of Cement ..... = 94 Lbs.
1 Bag of Cement ..... = 1 Cu. Ft.

4 Bags of Cement..... = 1 Bbl.
1 Bbl. of Cement..... = 400 lb. Gross, 376 lb. Net

Courtesy of Eddy Valve Company, Waterford, New York

Metric Conversion Table

Millimeters × .03937 = inches.
Millimeters ÷ 25.4 = inches.
Centimeters × .3937 = inches.
Centimeters ÷ 2.54 = inches.
Meters × 39.37 = inches (Act of Congress).
Meters × 3.281 = feet.
Meters × 1.094 = yards.
Kilometers × .621 = miles.
Kilometers ÷ 1.6093 = miles.
Kilometers × 3280.8693 = feet.
Square Millimeters × .00155 = sq. inches.
Square Millimeters ÷ 645.1 = sq. inches.
Square Centimeters × .155 = sq. inches.
Square Centimeters ÷ 6.451 = sq. inches.
Square Meters × 10.764 = sq. feet.
Square Kilometers × 247.1 = acres.
Hectare × 2.471 = acres.
Cubic Centimeters ÷ 16.383 = cubic inches.
Cubic Centimeters ÷ 3.69 = fl. drams (U. S. P.).
Cubic Centimeters ÷ 29.57 = fluid ounces (U.S.P.).
Cubic Meters × 35.315 = cubic feet.
Cubic Meters × 1.308 = cubic yards.
Cubic Meters × 264.2 = gallons (231. cubic inches).
Liters × 61.022 = cu. in. (Act of Congress).
Liters × 33.84 = fluid ounces (U. S. P.)
Liters × .2642 = gallons (231. cu. in.).
Liters ÷ 3.78 = gallons (231. cu. in.).
Liters ÷ 28.316 = cubic feet.
Hectoliters × 3.531 = cubic feet.
Hectoliters × 2.84 = bushels (2150.42 cu. in.).
Hectoliters × .131 = cubic yards.
Hectoliters ÷ 26.42 = gallons (231. cu. in.).
Grams × 15.432 = grains (Act of Congress).
Grams ÷ 981. = dynes.
Grams (water) ÷ 29.57 = fluid ounces.
Grams ÷ 28.35 = ounces avoirdupois.
Grams per Cu. Cent. ÷ 27.7 = lbs. per cubic inch.
Joule × .7373 = foot pounds.
Kilograms × 2.2046 = pounds.
Kilograms × 35.3 = oz. avoirdupois.
Kilograms ÷ 907.2 = tons (2,000 lbs.)
Kilograms per Sq. Cent. × 14.223 = lbs. per sq. in.
Kilogram-meters × 7.233 = foot lbs.
Kilograms per Meter × .672 = lbs. per foot.
Kilograms per Cu. Meter × .062 = lbs. per cubic foot.
Tonneau × 1.1023 = tons (2,000 lbs.).
Kilowatts × 1.34 = Horse Power.
Watts ÷ 746. = Horse Power.
Watts × .7373 = foot pounds per second.
Calorie × 3.968 = B.t.u.
Cheval vapeur ÷ .9863 = Horse Power.
(Centigrade × 1.8) + 32 = degrees Fahr.
Gravity Paris = 980.94 centimeters per sec.

POWER AND HEAT EQUIVALENTS

1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2550 B. T. U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

1 kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,653,200 foot-pounds = 3,600,000 joules = 3420 B. T. U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

1 horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2550 B. T. U. per hour = 42.5 B. T. U. per minute = 0.71 B. T. U. per second = 2.64 pounds of water evaporated per hour at 212° F.

1 kilowatt = 1000 watts = 1.34 horsepower = 2,653,200 foot-pounds per hour = 44,220 foot-pounds per minute = 737 foot-pounds per second = 3420 B. T. U. per hour = 57 B. T. U. per minute = 0.95 B. T. U. per second = 3.54 pounds of water evaporated per hour at 212° F.

1 watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B. T. U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 0.0035 pounds of water evaporated per hour at 212° F.

1 B. T. U. (British thermal unit) = 1052 watt-seconds = 778 foot-pounds = 0.252 calorie = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pounds of water evaporated at 212° F.

1 foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B. T. U. = 0.0000005 horsepower-hour.

1 joule = 1 watt-second = .000000278 kilowatt-hour = 0.00095 B. T. U. = 0.74 foot-pound.

EQUIVALENTS OF OUNCES IN WATER AND MERCURY

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
.3	.521	.038	8	13.9	1.020
.576	1.0	.073	9	15.6	1.148
1	1.7	.128	10	17.4	1.275
2	3.5	.255	11	19.1	1.403
3	5.2	.383	12	20.8	1.530
4	6.9	.510	13	22.6	1.658
5	8.7	.638	14	24.3	1.785
6	10.4	.765	15	26.3	1.913
7	12.2	.893	16	27.8	2.036

WEIGHTS OF MATERIALS

Pounds per Cubic Foot — Average

BRICK	
Common Red	100
Silica	105
CEMENT	
Portland	94
Hydraulic	60
COAL AND COKE	
Anthracite	53 to 57
Bituminous	49
Charcoal	18
Coke	26
CONCRETE	
Cement, fine	137
Rubble, coarse	119
EARTH	
Loam, dry, loose	76
Loam, packed	95
Loam, soft, loose mud	108
Loam, dense mud	125
LIME	
Quick, loose lumps	53
Quick, fine	73
LIME STONE	
Large blocks	168
Irregular lumps	96
MASONRY	
Granite or limestone	165
Mortar, rubble	154
Dry	138
Sandstone, dressed	144
METALS	
Aluminum	166
Brass, cast	524
Bronze	534
Copper, cast	537
Copper, rolled or wire	555
Iron, cast	450
Iron, wrought	482
Lead, cast	708
Lead, rolled	711
Steel, cast	490
Steel, rolled	495
Tin, cast	459
Zinc, cast	438
OILS	
Engine	55
Crude	48
Petroleum	55
Gasoline	43
SAND	
Dry and loose	100
Dry and packed	110
Wet and packed	130
Gravel, packed	118
Gravel, bank	111
Gravel, dry	74
WATER	
Water, as ice	59
Water, at 32° F.	62
Water, at 212° F.	60

Decimal Equivalents

of 8ths, 16ths, 32ds, and 64ths of an Inch

8ths

$\frac{1}{8} = .125$
$\frac{1}{4} = .250$
$\frac{3}{8} = .375$
$\frac{1}{2} = .500$
$\frac{5}{8} = .625$
$\frac{3}{4} = .750$
$\frac{7}{8} = .875$

16ths

$\frac{1}{16} = .0625$
$\frac{3}{16} = .1875$
$\frac{5}{16} = .3125$
$\frac{7}{16} = .4375$
$\frac{9}{16} = .5625$
$\frac{11}{16} = .6875$
$\frac{13}{16} = .8125$
$\frac{15}{16} = .9375$

32ds

$\frac{1}{32} = .03125$
$\frac{3}{32} = .09375$
$\frac{5}{32} = .15625$
$\frac{7}{32} = .21875$
$\frac{9}{32} = .28125$
$\frac{11}{32} = .34375$
$\frac{13}{32} = .40625$
$\frac{15}{32} = .46875$
$\frac{17}{32} = .53125$
$\frac{19}{32} = .59375$
$\frac{21}{32} = .65625$
$\frac{23}{32} = .71875$
$\frac{25}{32} = .78125$
$\frac{27}{32} = .84375$
$\frac{29}{32} = .90625$
$\frac{31}{32} = .96875$

64ths

$\frac{1}{64} = .015625$
$\frac{3}{64} = .046875$
$\frac{5}{64} = .078125$
$\frac{7}{64} = .109375$
$\frac{9}{64} = .140625$
$\frac{11}{64} = .171875$
$\frac{13}{64} = .203125$
$\frac{15}{64} = .234375$
$\frac{17}{64} = .265625$
$\frac{19}{64} = .296875$
$\frac{21}{64} = .328125$
$\frac{23}{64} = .359375$
$\frac{25}{64} = .390625$
$\frac{27}{64} = .421875$
$\frac{29}{64} = .453125$
$\frac{31}{64} = .484375$
$\frac{33}{64} = .515625$
$\frac{35}{64} = .546875$
$\frac{37}{64} = .578125$
$\frac{39}{64} = .609375$
$\frac{41}{64} = .640625$
$\frac{43}{64} = .671875$
$\frac{45}{64} = .703125$
$\frac{47}{64} = .734375$
$\frac{49}{64} = .765625$
$\frac{51}{64} = .796875$
$\frac{53}{64} = .828125$
$\frac{55}{64} = .859375$
$\frac{57}{64} = .890625$
$\frac{59}{64} = .921875$
$\frac{61}{64} = .953125$
$\frac{63}{64} = .984375$

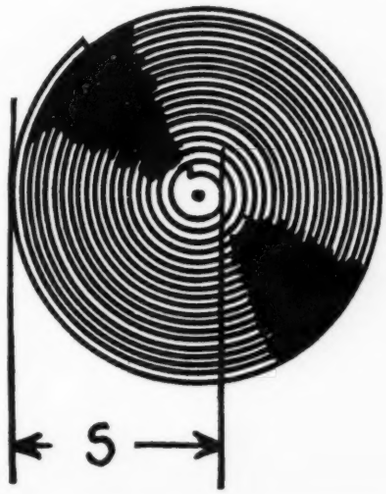
QUICK WAY TO ESTIMATE LENGTH OF MATERIAL IN ANY ROLL OR COIL*

MOST of us are users of considerable material that comes in rolls—paper, hose, belting, cables, wire, etc.—and the question often arises, "How much material remains in that roll?" Or, "Does the original roll contain full length?"

There are numerous formulas for computing lengths in rolls, but I find that all of them are more or less complicated. We are told to find the outside diameter, the inside diameter, then subtract, multiply, and do various other things, and finally we get the answer.

Here is a simple rule of my own derivation which I contend is the simplest possible: Make the one measurement "S," as shown in the sketch herewith, in inches. Then count the number of turns. Multiply the two together and then multiply that by 0.2618. The result is the length of material in feet.

For example, if the distance "S" is 10 inches, and the number of turns is 10, the roll contains 26.18 feet.



This holds true regardless of whether the material is paper, leather, or anything else. The thickness of the material does not make any difference.

To check the rule, take an instance where we have only one single turn of belting, the distance "S" being 10 inches. The roll, then, is a true circle, and the distance "S" is the diameter of that circle. The length of the belt, of course, is equal to the diameter times 3.1416 or, 31.416 inches. Now divide that by 12 inches and you will get 2.618 feet, as per the above rule.

Even if the roll is so tightly wound that there is no visible hole through it, the rule still holds true. And, ditto, if it is loosely wound.

*Contributed by W. F. Schaphorst, M.E.

ROOTS AND POWERS OF NUMBERS*

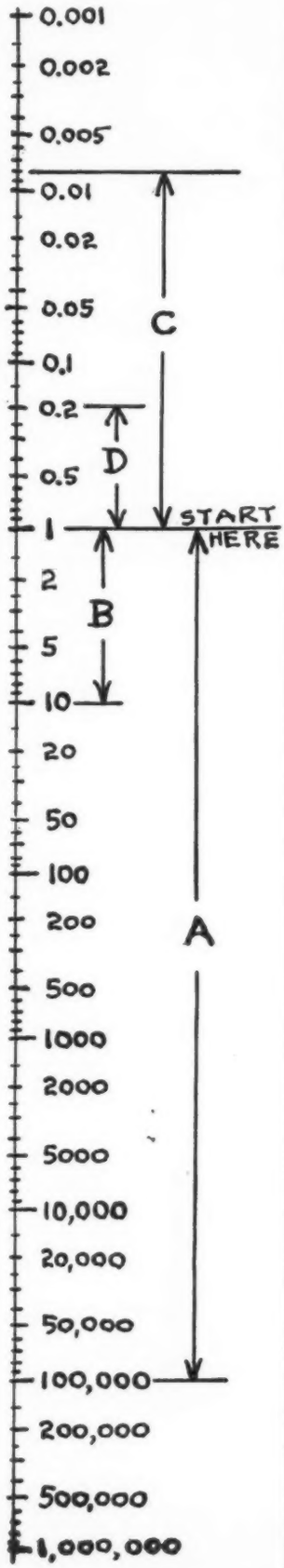
A Chart Which Saves Many Tables

Take any slide rule and lay it end to end nine times, and each time lay off the principal dividing lines, you will have a chart exactly like this one except that it will be much longer and therefore it will be much more accurate. That is what I did in preparing this chart. Then I reduced it to this much smaller size. To keep track of the digits you simply read the numbers exactly as they stand on the chart. No juggling of figures is necessary. I do not know of any other other method that is as simple as this. All other methods require "juggling of digits," as they say.

For example, what is the 5th root of 100,000? Measure the distance A from 1 to 100,000 as indicated on the chart. The distance B must then be exactly 1/5th of the distance A and there is your answer, namely, 10. In other words, divide the distance A by the root and the quotient shows you the distance to measure from 1 to find the answer. Always measure from "1" in either direction. "One" is always the starting point. To extract the square, cube, or other root of fractions is usually more complex than extracting roots of whole numbers. However, with this chart one is just as easy as the other.

For example, what is the cube root of .008? Measure the distance C from .008 to the starting point "1" and divide it by 3 and you get the distance D which tells us that the answer is 0.2.

A method that is as easy as any to find a third, fourth, fifth, etc., of any distance, is to use a pair of dividers. Adjust the dividers until you get the distance D exactly ⅓ of the distance C and the chart gives the answer without any mathematical calculations whatever. With this chart you can determine the 3.127 power for instance—any power in fact. And you can extract the 4.37 root or any other root, all without mathematical jugglery.



*From an article by W. E. Schaphorst, M. E., Newark, N. J., in WATER WORKS & SEWERAGE, January, 1939.

Inclined Diagonal Pipe Runs
Calculating Pipe Lengths

By CHARLES FRICK

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$
$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

L (θ) = 23° + and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc } (\theta) \qquad \text{Formula III}$$

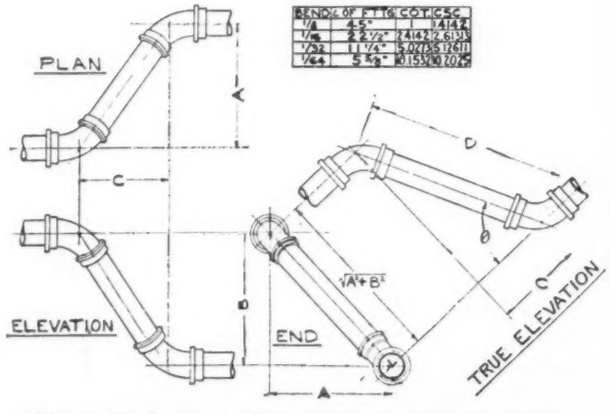
$$C = \sqrt{A^2 + B^2} \times \text{Cot } (\theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$
$$= \sqrt{64 = 90.25} \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a comment point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

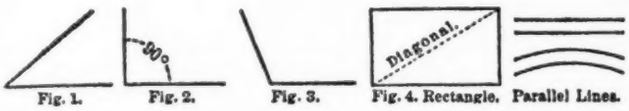


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

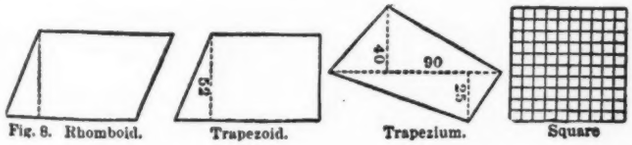


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

Fig. 9. Base.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

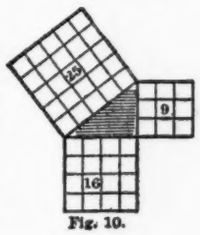


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)$=16$; of 3 (perpendicular)$=9$; the square root of their sum $(25)=5$, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods. Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ $63\frac{1}{4}$ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000 +$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square?

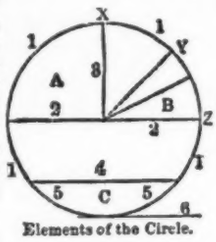
$35 \times 10 = 350$,
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

The Circle

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—$28 \times 3\,1/7 = 88$ in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—$144.5 \times 3183 = 46$ in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—$20^2 \times .7854 = 314.16$ sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—$50^2 \times 3.1416 = 7854$ sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

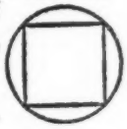
Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, $43560 \times .3183 = 13865$; $\sqrt{13865} = 117¾$ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.



The diameter of a log is 24 inches; how large a sill can be cut from it?

$24 \times .707 = 17$ in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—$12 \times 1.414 = 17$ in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—$20 \times 80 = 1600 \times .7854 = 1256.64$ sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—$50 \times .464 = 23.2$ in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

$(41 + 29) = 70 \times 3.1416 \div 2 = 110$ ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

$60 \times 40 = 2400 \times .7854 = 1885$ sq. ft. nearly.

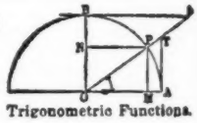
Polygons

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

$30^2 \times 433 = 389.7$ in. T; $10^2 \times 4.824 = 482.84$ in. O.



Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A_1 versed sine.
BN, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—$12^2 \times 6 = 864$.

How many cubic in. in a cubic foot?

Answer—$*12^3 = 1728$.

Find cu. ft. in a cu. mile.

Answer—$5280^3 = 147197952000$.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—$10½ \times 3 \times 1¼ = 39⅜$.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.

Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

$10^2 \times .433 \times 2 = 86.6$ sq. in. in area of the two ends.

$10 \times 25 \times 3 = 750$ sq. in. area of sides. $86.0 + 750 = 836.6$.

How many cubic inches in above prism, 10 by 25 inches?

Answer—$10^2 \times .433 = 43.3 \times 25 = 1082½$ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.

Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.

Cone.

Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$
3)549 (183, area of av. base of F. of sq. pyr.

183 × .7854 = 143.73 sq. ft., area of av. base of Fr. of cone.

143.73 × 10 = 1437.3 cu. ft. × 7.48 = 10751 gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\ 7/12$ sq. in., area of average base; $12\ 7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\ 7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

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METROPOLITAN WATER DISTRICT *of* SOUTHERN CALIFORNIA

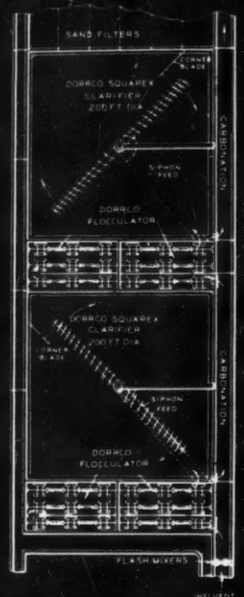
DORR-EQUIPPED for 100 M. G. D. of SOFTENING

DORR EQUIPMENT

Flash Mixing of Chemicals: 2 Dorrco Flash Mixers—three 27 in. turbo impellers each, rubber covered to resist abrasion.

Flocculation: 2 units of Dorrco Flocculators—200 ft. long, 50 ft. wide, 14 ft. deep—three rows of 12'-6" paddles per unit.

Sedimentation: 2 Dorrco Squarex Clarifiers—200 ft. square by 14 ft. side water depth—sludge thickening mechanisms and sludge wells in centers.



FACTS ON THIS PROJECT

TYPE—Lime-soda process, plus zeolite softeners.

CAPACITY—100 M.G.D. at present; 400 M.G.D. future.

LOCATION—La Verne, Cal.; 30 miles east of Los Angeles.

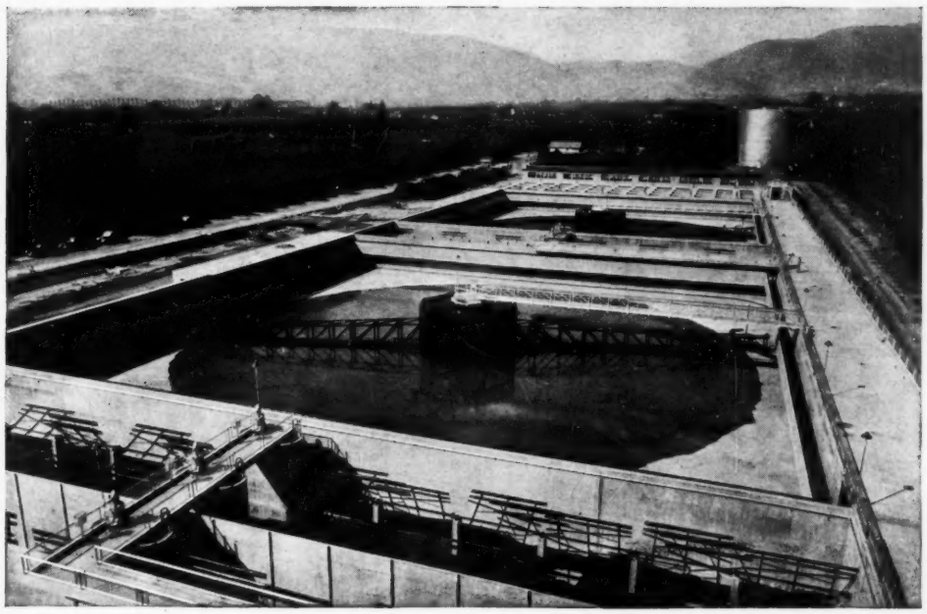
SOURCE RAW WATER—Colorado River, from Parker Dam—280 miles from softening plant.

AREA TO BE SUPPLIED—Los Angeles and 12 towns and cities on the south coastal plain.

RAW WATER HARDNESS—300 P.P.M. total (145 P.P.M. carbonate).

TREATED WATER HARDNESS—125 P.P.M. total.

REAGENTS—Lime, alum, soda ash, CO_2, chlorine, activated carbon.



▲ *Metropolitan Water District of Southern California, La Verne, Cal., 100 M.G.D., just before starting operations, May, 1941.*—Consulting Engineers: Hoover & Montgomery, Columbus, Ohio

A pair of 200 ft. Dorrco Squarex Clarifiers, each preceded by a triple row of Dorrco Flocculators, dominates this view of the 100 M.G.D. water softening plant of the Metropolitan Water District of Southern California. In the background, the San Bernardino Mountains; on either side, mile upon mile of orange groves.

Dorrco Squarex Clarifiers and Dorrco Flocculators, cast in bloc, are ideal running mates in water purification practice. Square sedimentation tanks, mean inexpensive, common wall construction—less cost per unit of area or volume—a compact, pleasing layout—and a minimum of interconnecting pipe lines and channels.

Cost comparisons—multiple square tanks plus Squarex's and Dorrco Flocculators—versus other tank shapes differently equipped, definitely favor this layout adopted so successfully by Metropolitan Water. Details on request.

★ *For full information on Dorr water treatment equipment, write for our two bulletins," Flocculation & Mixing" and "Sedimentation"*

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ITALY: S.A.I. Dorr-Oliver, Milan • JAPAN: Sanki Eng. Co., Ltd., Tokyo • SCANDINAVIA: A.B. Hedemora, Hedemora, Sweden • AUSTRALIA: Crossle & Duff Pty. Ltd., Melbourne
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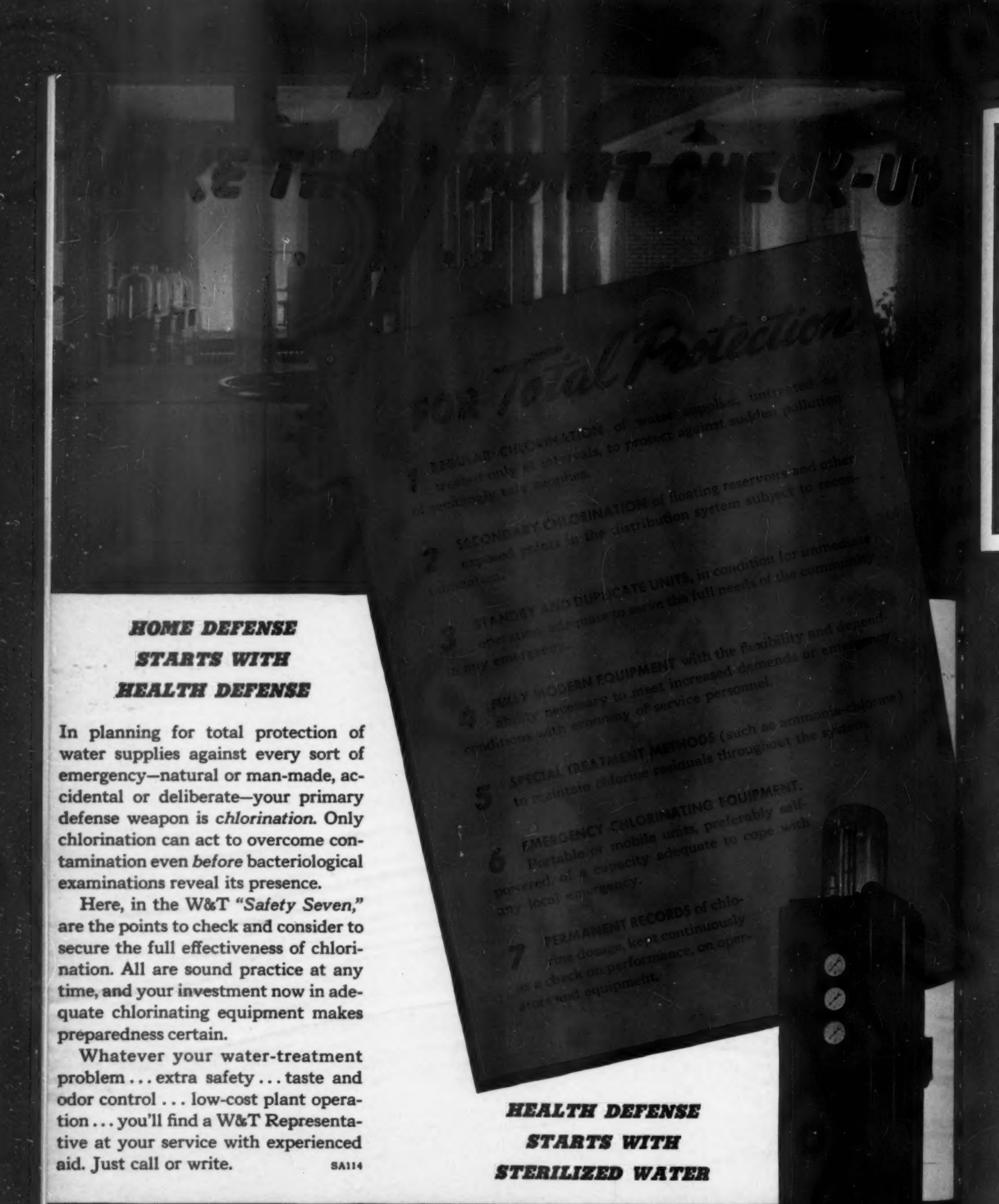
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1 REGULAR CHLORINATION of water supplies, untreated or treated only at intervals, to protect against sudden pollution or potentially early sources.
2 SECONDARY CHLORINATION of floating reservoirs and other exposed points in the distribution system subject to recontamination.
3 STANDBY AND DUPLICATE UNITS, in condition for immediate operation, adequate to serve the full needs of the community in any emergency.
4 FULLY MODERN EQUIPMENT with the flexibility and dependability necessary to meet increased demands or emergency conditions with economy of service personnel.
5 SPECIAL TREATMENT METHODS (such as ammonia-chlorine) to maintain chlorine residuals throughout the system.
6 EMERGENCY CHLORINATING EQUIPMENT. Portable or mobile units, preferably self-powered of a capacity adequate to cope with any local emergency.
7 PERMANENT RECORDS of chlorine dosage, kept continuously as a check on performance, on operators and equipment.

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